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# ***JPRS Report***

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# **Science & Technology**

***China***

SELECTIONS FROM 'CHINA TODAY: NUCLEAR INDUSTRY'

PART II

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## SCIENCE & TECHNOLOGY

### CHINA

#### SELECTIONS FROM 'CHINA TODAY: NUCLEAR INDUSTRY'

#### PART II

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Chapter 3. All-Round Self-Reliance and the Success of the First Nuclear Test: Section 4. Successful Explosion of the First Atomic Bomb Device [pp 52-65]

[Text] Although China had made preparations in the area of nuclear charges, achievement of the "2-year plan" on schedule demanded solution of many more problems to develop the atomic bomb.

1. Pushing construction of the Northwest Nuclear Weapons Development Base Area

The northwest Nuclear Weapons Development Base Area is located on the Qinghai Plateau at an average elevation of more than 3,200 meters. The mean annual temperature is minus 0.4° Celsius. It is a high, cold region with little oxygen, so the natural conditions are very harsh. Construction under such conditions was very difficult.

Moreover, the Northwest Nuclear Weapons Development Base Area was an enormous, technically complex project. It included several tens of engineering projects, installation of several pieces of a wide variety of equipment, strict technical requirements, and great difficulty. The arrangements made in the "2-year plan" and the demands of scientific research advances meant that this project basically had to be finished in 15 to 21 months. The region has a very short frost-free period, so little time was available for outdoor construction. Because project construction staffs at the time were inadequate, there were many problems in base area construction.

To deal with the situation in construction of the Nuclear Weapons Development Base Area and speed up project construction, the special commission of central authorities decided to reinforce construction staffs by transferring construction workers from 13 departments, including the Ministry of Construction,



Ministry of Railways, Ministry of Communications, Ministry of Water Resources and Electric Power, Corps of Engineers, Communications Corps, and others. They met with the No 103 and No 104 companies of the Second Ministry of Machine-Building Industry at the base area during the early stages and organized a construction site headquarters with Li Jue as general director for an all-round effort to push forward with construction. Preparations for construction began in March 1963 and the project was fully under way by May. As the projects were completed and went into use, the base area basically was finished by the middle of 1964, and it provided the necessary conditions for atomic bomb development.

Living conditions in the development base area were extremely hard. With support from related departments in the central authorities and Qinghai Province, a local government was set up and logistics systems established. These moves gradually improved employee living conditions and provided effective guarantees for base area construction.

## 2. People gathering in the northwest to launch a "great battle"

After the basic scientific research, production, and living conditions in the Northwest Nuclear Weapons Development Base Area were in place, the scientific research personnel assembled in Beijing began moving to the northwest in March 1963. Overall, the move went smoothly. A group of key technicians whose transfer was approved by the special central commission reported on time. Key leadership and technical cadres as well as working personnel from theoretical, experimental, design, production, and other fields gathered at the northwest base area and quickly began all-round development work. The development of China's first atomic bomb assumed the posture of an all-out attack at the northwest base area.

In August 1963, Minister Liu Jie [0491 2638] of the Second Ministry of Machine-Building Industry visited the base area to inspect the work. He decided to make the date on which the Soviet Union sent its letter refusing to provide mathematical models and blueprint data for the atomic bomb, June 1959, the number of the first atomic bomb, i.e., "596," as a means of encouraging the employees to be resolute in overcoming all difficulties and obstacles to develop the atomic bomb.

At the time, a key technical question with "596" was the need to test and confirm the theoretical design and experimental results. On 20 November 1963, a scaled-down fusion blast test was carried out. It fully confirmed the results of the theoretical design and experiments, and it laid a reliable foundation for the design of an atomic bomb.

## 3. A decisive decision made resolutely

At the same time as the blast experiment, experimental research concerning the explosive components was proceeding with urgency. Analytical comparisons and experimental examinations were made of two structural programs. To assure quality, preparations were made to carry out multiple programs simultaneously

for a small number of key components. This was necessary during the early stages of making attacks on key questions, when many paths could be explored and breakthroughs made, but it could not be continued for very long. If continued for too long, there would be too many models and forces would be scattered. Moreover, limited time was available to develop an entire atomic bomb, so several programs could not be carried out simultaneously. Prompt decisions and appropriate choices had to be made at the right times to organize focused attacks on problems and achieve rapid results.

In March 1964, Liu Jie again visited the front line and attended a scientific research conference. He felt that work for overall development was at the decisive stage and that a more realistic attitude should be adopted concerning the first atomic bomb test device. He called for basing product structure programs and explosive component processing techniques on the principle of feasibility to select one program in the beginning and test it as quickly as possible.

On the basis of smooth progress in all items of development and experiment, a full-scale blast simulation experiment was carried out on 6 June 1964. This was a comprehensive examination prior to the nuclear blast test. Although the nuclear charge was not made of active materials, the results of all experiments with actual materials to be used during the nuclear blast test conformed to expectations. By this time, work to develop the atomic bomb, which had begun in early 1960, had been under way for 4 years. After several small-scale experiments and a number of large-scale experiments, success was in sight.

#### 4. A completely successful test in explosion, measurement, and safety

On the afternoon of 11 April 1964, Zhou Enlai convened a meeting of the special central commission. They decided to use a tower explosion arrangement for the first blast test of an atomic bomb device. They called for the completion of all preparations before 10 September 1964 to achieve "guaranteed directions, measurements, and safety, success on the first try." The decision to conduct the test and the time to carry it out would be made after a decision by Mao Zedong and the CPC Central Committee Standing Committee. Thus, work to develop the first atomic bomb charge entered the final stage of completion, and national preparations prior to the test were going full bore.

China's first nuclear blast test was conducted under the personal direction of Zhou Enlai. PLA Deputy Chief of the General Staff Zhang Aiping [1728 1947 5493] was general director of the test site. Liu Xiyao [0491 6007 1031] was deputy general director, and Liu Jie in Beijing was responsible for contacts with central authorities from start to finish.

By 20 August, processing, assembly, testing, and acceptance of the test charge and all of the spare parts and components used in the first nuclear test were complete and they were shipped to the test site. Before startup of the experimental device, all areas made deployments and adopted extremely strict measures to guarantee safety throughout the entire transport process. Protected by all these safety measures, the experimental device and all of the components arrived at the test site on time.

Single item drills and comprehensive rehearsals were carried out between 23 August and 1 September. Thus, the call from central authorities to "complete all preparations before 10 September" was met 9 days ahead of schedule.

Based on the climatic conditions in the test site region, the central authorities set the time of detonation of the first atomic bomb device test (the technical term in zero hour) at 1500 hours on 16 October 1964. On the night of 15 October, operations personnel finished assembling the nuclear components in the atomic bomb. After placing it on the tower, connecting the detonators, and several other procedures, all of the personnel at the test site evacuated the target area and waited for "zero hour" to arrive.

As "zero hour" was sounded by the counter at the central control station 23 km from the test device, there was an intense flash followed by an earth-shaking roar, and then the enormous fireball turned into a mushroom cloud and burst into the sky. The first explosion of an atomic bomb device studied, designed, and developed in China was successful. Cheers echoed across the test site and all of the participants were moved to tears.

The test results confirmed that fairly high standards had been attained in China's first atomic bomb in the areas of theory, structural design, all components and assemblies, design and manufacture of detonation control systems, and all types of measurement and testing methods and equipment.

At 2200 hours on 16 October, the Central People's Broadcasting Station's evening news broadcast included several "news bulletins," a "Statement of the Government of the PRC," and the congratulatory telegram "The CPC Central Committee and State Council Warmly Congratulate the Magnificent Victory in the First Nuclear Test." RENMIN RIBAO also published a special issue for this purpose. The CPC Central Committee congratulatory telegram stated: "This successful test indicates that China has entered a new stage in national defense modernization. It is a strong blow to the American imperialist policies of nuclear monopoly and nuclear blackmail, and an enormous encouragement to all the peace-loving people of the world." The congratulatory telegram also pointed out: "The success of this test is the result of all the Chinese people holding high the magnificent red banner of Mao Zedong Thought, adhering to and implementing the overall CPC line of going all out, working vigorously to move forward, and building socialism through greater, faster, better, and more economical results, and the revolutionary spirit of self-reliance and working hard and aiming high; it is the result of the assiduous labor, cooperative efforts, and joint struggle of every region, ministry, committee, and military unit in China." The congratulatory telegram called on the relevant departments to work ceaselessly and unrelentingly, guard against arrogance and impetuosity, and struggle to scale new heights in science and technology, strengthen national defense, and defend peace in the motherland and world! Struggle for the complete prohibition and elimination of nuclear weapons!

The "Statement of the Government of the PRC" stressed that "China was forced to conduct nuclear tests and develop nuclear weapons. The Chinese government consistently has advocated a total ban on nuclear weapons. If this position can be achieved, there would be no need for China to develop nuclear weapons." "China has developed nuclear weapons for defensive purposes, safeguarding the Chinese people, and avoiding the risk of nuclear war launched by the United States. The Chinese government solemnly declares that at no time and under no circumstances will China be the first to use nuclear weapons." "The Chinese government solemnly proposes to all governments in the world that a conference of the heads of state of every nation be convened to discuss the question of a total ban and complete elimination of nuclear weapons. As the first step, the heads of all nations should agree that nations which have nuclear weapons and those nations which may have them in the near future should be responsible for assuring that nuclear weapons are not used, that nuclear weapons are not used on nations which lack nuclear weapons, that nuclear weapons never be used." "As always, the Chinese government will make every possible effort to use international discussions to promote the achievement of the magnificent goal of a total ban and the complete elimination of nuclear weapons. Until that day comes, the Chinese government and the Chinese people will be unwavering in taking their own path to strengthen national defense, safeguard the motherland, and protect world peace."

The success of China's first nuclear test aroused an enormous reverberation in China and foreign countries. People of all nationalities in China were overjoyed and unusually excited at hearing the broadcast. Everywhere they assembled for discussions, hailing the brilliant victory of the successful nuclear test. The spirits of the Chinese people were braced. Our compatriots in Hong Kong and Macao and overseas Chinese felt proud and elated and had an extremely strong sense of dignity, and they were happy to be the descendants of Yan Di and Huang Di [two of the earliest rulers of China]. The peace-loving nations and people of the world friendly to China all expressed their warmest congratulations and support. They felt that "People's China has broken down the walls of the nuclear club and aroused a true global revolution." "China having the atomic bomb is an effective guarantee of the ability to obtain peace in Asia and the world." In summary, the success of China's first nuclear test was an enormous encouragement to the people of all nations engaged in struggle and was a major contribution to the cause of safeguarding world peace.

#### Chapter 4. Obviating Interference and Advancing from Victory to Victory

[Text] The success of the first nuclear test indicated that national defense modernization in China had entered a new stage. It also indicated that China's nuclear industry had entered a new stage. The Second Ministry of Machine-Building Industry immediately summarized the achievements and experiences of the first stage and soberly estimated that although enormous achievements had been made in the first stage, they involved only breakthroughs in key areas; still, this laid a foundation upon which a go, no-go decision could be made. A new stage of development was to come, and the tasks were even more difficult and numerous. The opportunity had to be

seized to push on in the flush of victory. It was decided at the time that more important goals were to accelerate the conversion of the atomic bomb into a weapon and to make breakthroughs and master hydrogen bomb technologies; to speed up construction of a new scientific research and production base area; to transform strategic deployments in the nuclear industry; and to focus on research to develop a submarine nuclear power plant. China's nuclear industry began moving toward these new goals in 1965.

However, just when the nuclear industry was pushing forward in the flush of victory, the "Great Cultural Revolution" began. During the 10 years of chaos, Zhou Enlai and other elders of the proletarian revolution engaged in a resolute struggle with the counter-revolutionary clique of Lin Biao and Jiang Qing, and adopted a series of measures to protect the nuclear industry. The S&T personnel, employees, and leading cadres in the Second Ministry of Machine-Building Industry held firm to their posts and worked resolutely in the face of a complex situation of extreme chaos in China. They overcame all kinds of difficulties and successfully developed the hydrogen bomb and a submarine nuclear powerplant. They converted the atomic bomb and hydrogen bomb into weapons and completed a new strategic deployment in the nuclear industry. However, the interference and destruction created by the "Great Cultural Revolution" in the nuclear industry cannot be ignored.

#### Section 1. Speeding up the development of nuclear weapons

##### 1. "We should have both the atomic bomb and the hydrogen bomb"

In May 1964 and January 1965, while hearing reports on the Third 5-Year Plan and long-term planning ideas from the State Planning Commission, Mao Zedong raised the question of nuclear weapons development twice and pointed out clearly that: we must have the atomic bomb, and we must have the hydrogen bomb more quickly. Zhou Enlai also asked after the first successful nuclear test if it might be possible to speed up development of the hydrogen bomb, and he called on the Second Ministry of Machine-Building Industry to make comprehensive plans for the development of nuclear weapons.

On the instructions of the CPC Central Committee, the Second Ministry of Machine-Building Industry immediately began to study the formulation of a comprehensive plan to speed up the development of nuclear weapons.

First, they analyzed the situation. China's nuclear weapons research gained worldwide attention after the first successful nuclear test. The situation demanded that China speed up the pace of nuclear weapons development. Next, China's own conditions were analyzed. At the time, the U-235 production line had already gone into operation; the lithium deuteride-6 production line in the thermonuclear materials production line was to go into operation; construction of the reactor project in the plutonium production line was restored and progressing smoothly; new reprocessing techniques had been tested successfully, and the construction schedule for the reprocessing plant could be shortened. In the area of nuclear weapons development, there were reserve strength guarantees in technical and materials forces, and they had a rather good foundation. This situation showed that speeding up the pace of hydrogen bomb development was objectively possible.



After repeated study, the Second Ministry of Machine-Building Industry sent its "Report on Accelerating the Development of Nuclear Weapons" to the special central commission on 3 February 1965. The report called for speeding up the development of the atomic bomb into a weapon to deploy as a fighting force, and for speeding up breakthroughs in hydrogen bomb technologies to develop toward the advanced stage of strategic nuclear weapons. Zhou Enlai led the special central commission in discussing this report. They agreed in principle with the plan arrangements made by the Second Ministry of Machine-Building Industry and called for nuclear tests from 1965 to 1967 to complete work on making the atomic bomb into a weapon, and to strive to carry out a hydrogen bomb charge test in 1968.

## 2. Using the atomic bomb as a weapon

The first nuclear test merely involved detonation of a nuclear device. To make it a nuclear weapon, many weapons systems engineering research experiments had to be conducted on the basis of the requirements of means of delivery and tactical technologies.

The development of nuclear weapons in China began with research and testing of an atomic bomb device. Given the need for developing a weapon, this guiding ideology was rather clear. Arrangements for a nuclear aerial bomb had been made in the "2-year plan" outlined previously. The rather high technical standards of the atomic bomb device used in the first test permitted the schedule for its conversion into a weapon to be shortened. Only 7 months was needed from the success of the first nuclear device to the development of a nuclear aerial bomb (an atomic bomb delivered by aircraft) and a successful aerial drop test. Moreover, only 2 years was needed for development of a nuclear warhead and a successful test flight of it carried by a missile.

At the time of the first atomic bomb charge research experiment, the Second Ministry of Machine-Building Industry cooperated with the Ministry of Aeronautics, Ministry of Electronics Industry, Ministry of Ordnance Industry, Ministry of Astronautics (which was the Fifth Institute of the Ministry of National Defense at the time), and other departments to undertake work to develop an atomic aerial bomb. By the time of the first successful atomic bomb charge test, the structure, overall configuration, and design of the detonation control system for the aerial bomb had been decided upon, and the refitting of an aircraft for transporting the aerial bomb was finished. Based on the environmental demands of transport aircraft and missiles and on the experience of the first nuclear test, the Beijing Institute of Nuclear Weapons improved the design of the theoretical model and the structure of the nuclear device and improved its reliability. Afterwards, they conducted several simulations and actual tests of the components and the entire bomb which confirmed that the product could meet the environmental conditions of transport and installation on an aircraft, and that it could meet tactical and technical requirements. In the end, it was approved by the central authorities and an aerial drop test of a nuclear aerial bomb was conducted on 14 May 1965. The test was successful and the power of the blast was basically identical to theoretical calculations. From this point on, China had nuclear weapons available for actual use in war.

A nuclear missile is a nuclear weapon carried by a guided missile, and is even more advanced than a nuclear aerial bomb. After China's success in developing missiles, nuclear weapons development departments faced the task of providing a nuclear warhead for installation in a missile. A nuclear missile warhead is much smaller in volume and weight than a nuclear aerial bomb, and the environmental conditions required are even more complex and exacting. All of the S&T personnel embodied the revolutionary spirit of not fearing difficulties and working persistently and unremittingly. Beginning in April 1964, on the basis of the design of the first atomic bomb and in conjunction with the requirements of a guided missile, they designed a nuclear warhead and also did a large number of technical, blast, and environmental experiments. In the end, they examined and confirmed the performance of the nuclear warhead they had developed under in-flight conditions, and they conducted full-equivalent and full-range nuclear flight tests of an atomic bomb fitted to a missile. These tests were quite dangerous, so the special central commission held a special discussion on safety in the experiment. Zhou Enlai personally made detailed and careful arrangements. The requirements were discussed repeatedly and several simulation experiments were conducted, so troublesome problems were solved one after another. In the end, Nie Rongzhen personally visited the site to direct the operations. A successful missile nuclear weapons test was conducted on 27 October 1966. During the test, the missile flight went routinely, it flew accurately to the target area, and a nuclear detonation of the nuclear warhead occurred at the predetermined altitude. Mao Zedong happily pointed out that people had said that China was unable to develop missile nuclear weapons, but we had them now!

### 3. Making rapid progress in breakthroughs in hydrogen bomb technologies

Development of a hydrogen bomb is even more complex than the atomic bomb in terms of theory and manufacturing technologies. At the time, other nations were quite secretive about the hydrogen bomb, which made breakthroughs even more difficult because we had to rely completely on our own explorations.

Where should the explorations begin? Back in December 1960, Liu Jie had pointed out that, given that the Beijing Institute of Nuclear Weapons was busy with key atomic bomb projects at the time, the first steps in theoretical explorations of the hydrogen bomb could be done at the Institute of Atomic Energy. The Institute of Atomic Energy had established the "Neutron Physics Leadership Group" in 1960 under the direction of institute Director Qian Sanqiang [6929 0005 1730] and organized Huang Zuqia [7806 4371 3174], Yu Min [0060 2404], and other theoretical research personnel to begin basic research on the properties of thermonuclear materials and the mechanisms of thermonuclear reactions. In October 1964, after completing development work on the atomic bomb, the Beijing Institute of Nuclear Weapons decided to shift one-third of its theoretical research personnel into comprehensive theoretical research on the hydrogen bomb. In January 1965, the Second Ministry of Machine-Building Industry also transferred scientific research personnel in the Institute of Atomic Energy who had been engaged in explorations into hydrogen bomb research to the Beijing Institute of Nuclear Weapons to concentrate forces for research on principles, structures, materials, and other subjects.

The leaders at the Beijing Institute of Nuclear Weapons encouraged the research personnel to abandon the ideology of making arrangements according to seniority. Regardless of whether they were older scientists or young intellectuals who had just taken up the work, all of them were called upon to be bold in their ideas and propose many programs. After research, analysis, supplementation, and perfection, they selected two routes for attacks on key questions. They also decided to start at a low level and strive to reach higher levels, and thereby affirmed the main direction of attack in explorations of principles.

After several months of arduous explorations, they had clarified technical lines for attacks on key questions. On this foundation, the Second Ministry of Machine-Building Industry submitted its report "Arrangements for Work To Make Breakthroughs in Hydrogen Bomb Technologies" to the special central commission in August 1965. They were to carry out theoretical explorations, conduct several nuclear tests, and use experiments to determine whether or not their theories were correct and improve theoretical understandings. The special central commission agreed to these arrangements and called on all relevant departments to provide active assistance and attack several key questions.

Although preliminary plans had been made for hydrogen bomb research experiments, there were problems with nuclear materials. To fight for time, the Beijing Institute of Nuclear Weapons decided to focus on materials and attacked key technical questions concerning the hydrogen bomb using existing nuclear materials to take a new path in hydrogen bomb development.

Based on the line determined for nuclear materials, some of the theoretical personnel in the Beijing Institute of Nuclear Weapons spent more than 2 months starting in late September 1965 making difficult computations and analytical explorations. They eventually found the key to the conditions required for a sustained thermonuclear reaction and they explored new theoretical programs to develop the hydrogen bomb. This was the key breakthrough in hydrogen bomb development. The specialists in the Beijing Institute of Nuclear Weapons confirmed this type of new theoretical program. In December 1965, a planning conference directed by Wu Jilin [0702 7139 7207] was held at the Northwest Nuclear Weapons Development Base Area. The discussions concerned a 2-year plan for 1966 and 1967 for scientific research and production of the hydrogen bomb. The conference agreed with the principle suggested by Liu Xiyao of "making breakthroughs in the hydrogen bomb, preparing with both hands, focusing on new theoretical programs." This meant working on new theoretical programs focused on the development of a nuclear warhead carried by a guided missile, which required that a corresponding new "thermal" experiment be added, in conjunction with continued attacks on key problems in the original hydrogen bomb program. The special central commission approved this plan, and it decided on a tower detonation arrangement using the iron tower prepared for the first nuclear blast for the new "thermal" experiment.



The decision to concentrate on new theoretical programs for breakthroughs in the hydrogen bomb focused theory, experiment, design, production, and other areas on a new goal, and all areas of development and experiment work proceeded effectively according to plan. There was a successful test of an atomic bomb containing thermonuclear materials on 9 May 1966. The process of the thermonuclear reaction basically conformed to the theoretical predictions and provided important data concerning hydrogen bomb design. A test of hydrogen bomb principles based on the new theoretical program design was conducted on 28 December 1966. The results showed that the new theoretical program was feasible, advanced, simple, and convenient. Based on the results of this test, the special central commission decided to discontinue research on trial development of an aerial hydrogen bomb, concentrate forces for design based on the new theoretical program, and conduct a direct test of a full-equivalent hydrogen bomb.

By May 1967, processing and assembly of the first hydrogen bomb and preparations for the test were complete. At the same time, consideration was given to using an aircraft in-flight drop to carry out this large-equivalent test. Safety work was extremely important and all of the relevant departments made careful arrangements for detonation control systems, refitting an aircraft to carry the bomb, the release altitude, parachute development, and other topics. The relevant safety work discussions were carried out under the organizational leadership of the National Defense Science Commission with the participation of the Nuclear Test Base Area, the Ministry of Aeronautics, the PLA Air Force, and other units. On 9 May 1967, Zhou Enlai chaired the 18th meeting of the special central commission to re-discuss preparations for the hydrogen bomb test. It was felt during the meeting that China's first full-equivalent hydrogen bomb test was extremely important politically and that militarily, it would push nuclear weapons technologies in China into a new development era. It called for the completion of preparations for the test by 20 June 1967. In addition, precise meteorological data for June and July for the test site area and the region the smoke cloud would pass over were submitted from 1 to 10 June and a new date was set for the test. National Defense Science Commission Deputy Director Zhang Zhenhuan [1728 7201 1403] and Vice Minister Li Jue [2621 6030] of the Second Ministry of Machine-Building Industry participated in the leadership work.

To assure safety and success in the experiment, a comprehensive rehearsal of the detonation control system was carried out prior to the formal test using an inactive nuclear charge.

On 17 June 1967, under arrangements made personally by Zhou Enlai, Nie Rongzhen went to the site to provide direction. China's first hydrogen bomb blast test was successful, achieving Mao Zedong's prediction of June 1958 that "I think it is entirely possible that we will develop the atomic bomb and hydrogen bomb within 10 years" ahead of time. The United States spent 7 years and 4 months between its first atomic bomb test and its first hydrogen bomb test. The Soviet Union took 4 years, England took 4 years and 7 months, and France spent 8 years and 6 months. China, however, spent only 2 years and 8 months, so our speed of development was the fastest. China's first hydrogen bomb blast test moved us ahead of France and aroused a huge world reaction. It was acknowledged that China's nuclear technology had moved into the ranks of the advanced nations of the world.

## Chapter 11. Reprocessing of Spent Fuel [pp 216-226]

[Text] When nuclear fuels are "burned" in the fission reaction which takes place within a reactor, their physical properties and chemical composition are changed. After a certain point (usually expressed as "depth of burnup"), there is an obvious reduction of fissionable materials in the fuel, meaning that they have been "exhausted" by combustion. In addition, the fission products can absorb large amounts of neutron neutrinos (called neutron poisons) which can grow steadily until the irradiated fuel elements must be removed from the reactor and allowed to "cool" for a period of time. When there is an obvious attenuation in radioactivity, the elements must be put through several chemical processes to recover and extract the valuable materials they contain. This is called "post-processing of irradiated fuels," "post-processing of exhausted fuels," or simply "reprocessing."

Usually, reprocessing plants can be divided according to the nature of their production into the two main categories of military plants, which process production reactor fuels, and commercial plants, which process power reactor fuels.

The main task in China's military reprocessing plants is to extract military plutonium with a high concentration of plutonium-230. Their secondary task is to recover depleted natural uranium. The plutonium products from the plants are provided for use in nuclear weapons. The uranium products are converted and shipped to uranium isotope separation plants for enrichment by the diffusion method, forming a nuclear fuel recycling system. In the area of development, the industrial plutonium extracted from irradiated power reactor fuels in China also should be returned to element manufacturing plants for remanufacture into reactor fuel elements. Thus, reprocessing is an indispensable link in the nuclear fuel cycle.

Reprocessing usually involves three stages: (1) A cooling process. The irradiated fuel pulled from the reactor must be set aside for a period of time, both to allow the uranium-237 in it to decay into neptunium-237 to facilitate its elimination during chemical separation, and to allow the short half-life fission products in it to "die out," which rapidly attenuates their radioactivity and thereby simplifies reprocessing. Generally speaking, the fuel from a production reactor must cool for at least 100 days. The fuel from a power reactor must cool for 1 to 2 years or even longer. (2) Front-end process. A chemical method usually is employed for the aluminum-clad metallic uranium elements used in production reactors. First, an alkali is used to dissolve the casings and then nitric acid is used to dissolve the uranium cores. A combined mechanical-chemical method is used for power reactor elements. First, they are broken mechanically into small pieces, after which a nitric acid bath is used to dissolve the cores. (3) Chemical separation. This has undergone almost 40 years of development. All nations of the world use a wet processing method. The most common method is a Purex solvent extraction process which first uses tri ester phosphate as an extractant and nitric acid as a salting-out agent. The first stage, cooling, usually is done in a water tank attached to a reactor site or reprocessing plant. The two subsequent stages are carried out in sequence at a reprocessing plant.

The main characteristics of reprocessing are: (1) The irradiated fuel is extremely radioactive, so equipment operations must be carried out remotely and the materials used must be tolerant to intense irradiation. To guarantee the safety of operating personnel, various measures must be employed to prevent external and internal radiation of the human body by radioactive materials, so the waste requires additional processing and handling. (2) There is a risk of criticality accidents occurring in the fissionable materials, and suitable preventative measures must be adopted. (3) High demands are placed on the purity of the extracted and recovered materials. The products usually cannot contain contaminants of more than a few parts per million or even a few parts per billion. (4) The main products are quite expensive, so there must be a high recovery rate throughout the entire process. These characteristics make reprocessing plants expensive and technically complex, and they place high safety demands on them.

China's reprocessing industry started with the precipitation method provided via Soviet assistance in 1956. After the cutoff of external assistance, S&T personnel continued working for a period of time on the basis of Soviet-supplied designs and technical programs while preparing for construction. In 1964, based on scientific research in China, the S&T personnel decided to abandon the precipitation method and adopt the advanced solvent method. A pilot reprocessing plant was completed in September 1968. China's military reprocessing plant went into formal operation in April 1970. Afterwards, S&T personnel also did much scientific R&D design preparation work to reprocess power reactor and research reactor fuels.

The technologies chosen for China's reprocessing plants attained advanced international levels in on-line analysis technologies, chemical reagent consumption standards, and other areas, but there are discrepancies in certain types of equipment, instruments, automatic control systems, overhaul, and other aspects. Operating experience accumulated over several years in the military reprocessing plant and the large amount of preparatory work undertaken for power reactor fuel reprocessing laid an excellent foundation for development of China's nuclear power industry, "basing nuclear materials on Chinese sources," and forming a complete nuclear fuel cycle system in China.

## Section 1. Choice of the technology for spent fuel reprocessing

### 1. Starting with the precipitation method

In 1956, China began to make plans to build a reprocessing industry. Compilation of design and plan task documents, selection of a site, and other preparations for a reprocessing plant were done in 1957. On 30 January 1958, it was decided that China's first military reprocessing plant would be built at the Jiuquan Integrated Atomic Energy Enterprise in Gansu Province.

Next, China established the Design Academy and the CAS Academy of Atomic Energy Reprocessing Research Office for the special purpose of atomic energy industry design. Qinghua University and Beijing University previously had added majors in the radiation chemistry industry and radiation chemistry. The design, scientific research, and educational personnel in these units constituted the first technical forces for China's reprocessing industry.

Soviet specialists began arriving in August 1958 to work in the relevant units in China. The Design Academy of the Second Ministry of Machine-Building Industry (the Beijing Nuclear Engineering Research and Design Academy) sent a 14-member group to the Soviet Union in April 1958 to participate in preliminary design. The Soviet Union proposed a design task document in late 1958, and a preliminary design document was issued in early 1959.

The technology proposed by the Soviet Union at that time was the precipitation method. This process was tediously long and required an enormous plant building. The amount of stainless steel required alone was almost 10,000 tons. Moreover, it operated intermittently, which was extremely inconvenient. It also created substantial amounts of waste liquid and product recovery rates were rather low. At the time, the technical documents sent to the Design Academy by the Soviet Union only accounted for about 20 percent of the construction diagrams for eight auxiliary projects. The core technologies concerning the uranium/plutonium separation plant had not been received. On 22 August 1960, all the Soviet experts working in the Design Academy left and ceased to provide any data. After this, the Second Ministry of Machine-Building Industry's Design Academy adhered to the principle of "total reliance on our own efforts," proposed 145 experimental demands to the Institute of Atomic Energy based on problems in the original Soviet design, and restudied the project program. During this period, the Reprocessing Research Office in the Institute of Atomic Energy added to its research personnel and improved its research facilities. They tested, verified, and gained a full understanding of the chemical conditions required for the precipitation process, and they studied separation and analysis of plutonium and fission products, and certain basic technical questions. Working under simple and crude conditions, the research personnel in this office extracted the artificial radioactive element plutonium from the irradiated research reactor fuel in March 1962 and met scientific research needs at the time. Also participating in research on the precipitation method at the time were the CAS Changchun Applied Chemistry Institute, the Beijing Chemistry Institute, the Shanghai Organic Chemistry Institute, the East China College of Chemistry, and other units.

After earnest study of the original Soviet design program, the Design Academy felt that too much work and too many technical problems were involved in this program design. Moreover, the large plant used excessive amounts of materials and there was a particular problem with inadequate supplies of stainless steel in China. For this reason, Liu Yunbin [0491 0336 2430] and some technical personnel in the Design Academy suggested that a smaller scale pilot plant should be built first. This proposal was approved by higher authorities.

During the first half of 1963, the Second Ministry of Machine-Building Industry organized intermediate examination and approval of the expanded preliminary design for this purpose. To achieve a total solution to unsolved technical problems with the precipitation method, a conference of all scientific research units outside the Second Ministry of Machine-Building Industry was held in Changchun in August 1963 to lay all the technical cards on the table. All personnel at the meeting felt that the precipitation method

obviously was backward. Given the situation with progress in work at the time, however, the conference decided that, with the exception of continuing to study the extraction method at Qinghua University, the other units would continue to focus on key problems with the precipitation method. To reinforce leadership, key technical problems in plant construction were cleared up first, and by the end of 1963 the Second Ministry of Machine-Building Industry had established a "leadership group for attacks on key problems in nuclear fuel reprocessing."

Although only the design of a pilot plant using the precipitation method had been completed and it had not actually been built, work over the years in scientific research and in design had provided excellent training for the technical staffs who were not fully mature shortly before construction. They improved their knowledge and skills during construction and laid an excellent foundation for future innovation and development.

## 2. Research on solvent extraction method

As the world's atomic energy industry continued to grow from 1955 to 1958, two international conferences on the peaceful use of atomic energy were convened by the United Nations in Geneva, Switzerland. Collections of documents from these two conferences and the "Reactor Handbook--Second Volume Fuel Reprocessing" (2nd edition) published later in the United States, as well as a multitude of reports from atomic energy organs in many countries continued to arrive in China, and they included a substantial number of documents related to reprocessing from the United States, England, France, and other countries. This information provided S&T personnel working in China's reprocessing industry with a timely understanding of world technical levels and development directions at the time. It was apparent from them that the trend of developments in reprocessing technologies was a shift from the precipitation method of the 1940's to the solvent method which had appeared during the 1950's.

In late January 1959, in its "Report on Proposals To Study the Use of Extraction Method Technologies" submitted to the Second Ministry of Machine-Building Industry, the Design Academy pointed out that: "production via the extraction method will become one direction of development in radiation chemistry plants." "We feel that greatly expanded research on extraction method technologies is an urgent topic...study and early completion of the extraction method will be very important for catching up to and surpassing international levels in radiation chemistry production." At the same time, scientific research personnel in the Institute of Atomic Energy also did a considerable amount of research on extraction, ion exchange, high temperature region smelting in a dry process, and other separation techniques.

Qinghua University did much early exploratory work in studies on the extraction method. During the late 1950's, scientific research personnel in the Radiation Chemistry Education Group in the Engineering Physics Department at Qinghua University and the Artificial Radioactive Element Chemistry Technology Education Group formed shortly afterwards (and transferred later to the

Engineering Chemistry Department) undertook wide-ranging laboratory research under the leadership of Professor Wang Jiading [3076 1367 7844] and Associate Professor Teng Teng [3326 5671]. Later, they also worked under unified arrangements by the Second Ministry of Machine-Building Industry. Besides the related teachers, the participating personnel included graduates of the six classes between 1960 and 1965 and certain graduate students. They focused on this special topic to complete several scientific research reports, graduation theses, and graduation designs. The main work during this period included: research on the chemical and technical conditions for extraction of uranium, plutonium, and several other important fission product elements in a tri-ester phosphate (diluted with kerosene)--nitric acid solvent liquid system (including measurement of single-level equilibrium distribution ratios and tandem simulated countercurrent extraction test tube experiments); solvent selection, pre-processing and purification methods, and research on the mechanisms of radiation chemistry and irradiation stability during the extraction process; research on small-scale extraction equipment--pulse sieve plate columns, compound clarification tanks, and so on. These advanced explorations played a role in promoting changes in reprocessing technologies in China. Some research achievements, such as the combined positive/negative pressure air pulse-stirred clarification tank based on a Canadian prototype, selection of primary technical conditions and some analysis methods, and so on, became important bases for future continuous countercurrent hot experiments and equipment-amplified cooling experiments.

### 3. An important decision to shift from precipitation to extraction method

The most important year during the developmental history of reprocessing technologies in China was 1964.

In March 1964, with permission from the National Defense Industry Office, the Second Ministry of Machine-Building Industry invited seven nationally renowned chemists and chemical industry specialists from outside the ministry to assist in examination of the technical design for the pilot plant. In April 1964, an office conference in the Second Ministry of Machine-Building Industry decided that the pilot plant would continue to use a process design based on the precipitation method and that preparations would be made for production. To determine whether or not a large plant could adopt the new process, a survey group composed of relevant personnel from the Institute of Atomic Energy, the Design Academy, the Scientific Research Bureau of the Second Ministry of Machine-Building Industry, and Qinghua University was organized under the leadership of Institute of Atomic Energy Deputy Director Professor Wang Dexi [3076 1795 3556] and Design Academy Chief Engineer Ye Decan [0673 1795 2402]. Scientific research units in Beijing, Shanghai, Hengyang, and other regions as well as the Dressing and Smelting Plant examined operational conditions of the extraction equipment--the pulse sieve plate column, the packing column, and the compound clarification tank. The survey concluded that China could solve technical problems with the extraction method and that it was economically superior to the precipitation method. The survey group proposed that the large-plant technology in the original design be changed to the extraction method and that the Institute of Atomic Energy, Qinghua University, and reprocessing plant make a joint attack on key technical questions.



During this period, the Design Academy also set up a comprehensive group to study engineering design programs for extraction technologies and to hold debates on the column and tank varieties of extraction equipment. In May 1964, the comprehensive group also proposed that the first stage of the project (the pilot plant) should use the precipitation method program and that the second stage of the project (the large plant) should use extraction method technologies. On 20 May 1964, the Second Ministry of Machine-Building Industry decided to adopt the extraction method during the second stage of the project and to cease work related to the use of the precipitation method in this project.

In August 1964, a conference to examine and approve the design for the first stage of the project was held in Qingdao. Chief Engineer Jiang Shengjie [1203 5110 7132] from the Jiuquan Integrated Atomic Energy Enterprise played a major role in examining the design for the first period project. After careful examination, most delegates at the conference leaned toward rejecting the precipitation method, but in consideration of the situation in design progress at the time, they still approved the precipitation method design for the first period project to speed up the pace. They also decided to accelerate the pace of research on the extraction method and to perfect the required experimental conditions as quickly as possible.

On 16 October 1964, China carried out its first successful nuclear test. This success greatly encouraged the S&T personnel in the reprocessing industry. On 10 November 1964, Chairman Mao Zedong called for a revolution in design. The design personnel made their final attack on the outmoded technology used in the precipitation method and quickly prepared a preliminary plan for a shift to the extraction method in the pilot plant. After soliciting opinions on this question, leaders in the Second Ministry of Machine-Building Industry quickly gave their approval. On 11 December 1964, the Second Ministry of Machine-Building Industry gave formal notice that "construction of the pilot plant designed for the precipitation method should stop and work to study and design extraction technologies should be speeded up."

From this point on, precipitation technologies were totally abandoned and China's reprocessing industry advanced toward extraction method technologies.

#### 4. Hot test on a small scale

In the situation outlined above, it was imperative that research on the extraction method be carried out under "hot" (intensely radioactive) conditions. In early December 1964, several professors and students at Qinghua University studying solvent irradiation chemistry worked with S&T personnel from the Institute of Atomic Energy to use a hot room (a small room screened with thick concrete used for work with highly radioactive materials) in a reactor building to carry out single-level extraction and emulsification experiments under simulated conditions of intense irradiation (external irradiation of the hot uranium elements placed around the beakers used in extraction). After about a month of air pulse stirring, the biphasic extractant system in the beakers produced no serious emulsification and phase

separation remained excellent. Since the experiment was carried out under simple and crude conditions that approximated real ones, the prospects were considered hopeful. As the end of 1964 approached, tasks involved in small-scale hot experiments with the extraction method were formally assigned. This experiment involved a new topic (it was a pioneering undertaking in China), intense radioactivity, and complex technologies, and there were pressing time demands. To reinforce leadership, unify deployments, and better concentrate forces in all areas, personnel from the Institute of Atomic Energy, Qinghua University, the Design Academy, and the reprocessing plant were transferred and placed under the leadership of Associate Professor Zhu Yongjun [2612 3057 6296 + 44213] of Qinghua University, Lin Zhangji [2651 3361 1015] and Luo Wenzong [5012 2429 1350] of the Institute of Atomic Energy, and others to form two groups of shock troops (with a total of 81 people) to tackle key technical problems. The first group of shock troops started overcoming difficulties in January 1965 and transformed the physics hot room used to examine irradiated elements into a chemistry hot room with many intake pipes. Within 4 short months, they formed semi-transparent epoxy resin into a platform-size compound clarification tank and carried out a total of 11 hot experiments on the critical links in reprocessing technologies of joint uranium and plutonium decontamination and uranium-plutonium separation. The operational results showed that the technical performance of the extraction method was excellent.

Next, China's first hot chemistry laboratory with five hot rooms was completed at the Institute of Atomic Energy (see Figure 14). The second group of shock troops worked there to carry out experiments for a second extraction cycle on the plutonium line. Altogether, they did eight small-tank countercurrent experiments and some test tube tandem experiments to explore optimum technical parameters. The Reprocessing Research Office and Analytical Research Office in the Institute of Atomic Energy also had nearly 100 personnel responsible for front-end casing dissolution, plutonium tail-end anion exchange purification, oxalytic precipitation roasting, and many strenuous sample sub-assembly and analysis tasks. Afterwards, the Reprocessing Laboratory independently completed eight hot solvent re-use experiments.

All personnel in the shock brigade in the Institute of Atomic Energy displayed a spirit of large-scale cooperation, pooled their collective wisdom, and fought in round-the-clock shifts. To save time, some people slept in their offices when the work was urgent. Many worked through their spring holidays. Once, a crack caused by aging appeared in one of the air pulse tubes of a tank, and they had to determine if a single-path pulse would affect technical performance or not. An urgent telegram was sent to Qinghua University. The professors and students there fought for every second, experimented through the night, and reported their results on the morning of the second day. China's first generation of mechanical hand operating personnel displayed a high degree of skill. After the leak was covered with rubberized fabric, the tank continued to operate. When a highly radioactive feed tube developed a leak, several personnel worked to eliminate the trouble without waiting for the hot room to be flushed down to permissible levels and went to make the repairs, facing high radiation doses with only gas-protection clothing.



To obtain complete and reliable experimental data and to extract a certain amount of plutonium products, small-scale hot experiments also proceeded simultaneously at the Qinghua University Nuclear Energy Technology Institute located near Nankou in the southern suburbs of Beijing. To improve experimental conditions at Qinghua University, after receiving approval from the State Council and the special central commission, the Second Ministry of Machine-Building Industry and the Ministry of Higher Education jointly decided to build a hot chemistry laboratory in the institute. Premier Zhou Enlai approved a special grant for construction. The design of project and experimental equipment was completed in 1964, and construction began at the end of the year. With support from several manufacturing plants, all of the equipment and instruments were completed on schedule. This was particularly true of the 60 mature technicians and technical personnel sent from the reprocessing plant who greatly accelerated the pace of construction and installation. In just a little more than a year's time, the Hot Chemical Laboratory, which included two rather large hot rooms, two greenhouses, and two large organic glass glove boxes, was completed.

In the spring of 1966, the experimental equipment was installed and debugged. Cold experiments were conducted in late April. In early June, the first hot experiment went off successfully. At exactly this time, the "Great Cultural Revolution" began. Should they shut down, or should they continue? This was the question everyone faced. At this key moment, Premier Zhou Enlai issued instructions regarding this task in late August. Vice Minister Li Jie of the Second Ministry of Machine-Building Industry went to the site for persuasion and mobilization. Thus, with the exception of some school graduates, some of the educational employees, and an extremely small number of people in the Design Academy, most of the other personnel eliminated the interference, remained faithful to their posts, and eventually completed the tasks involved in 14 hot experiments, exceeding their duties, in late September.

The experiments at Qinghua University basically were confirmed by a one-time deployment of the full process based on the design of the pilot plant which had a daily processing capacity of 4 kg of uranium.

The experiments at Qinghua University also embodied the spirit of large-scale cooperation. A total of 200 to 300 people participated in the experiment. Besides the teachers, employees, and some classes of graduates at Qinghua as well as technical personnel in the Design Academy, the reprocessing plant sent several personnel who were trained and drilled at every operating post. Most of those fighting at the front line were young people who had just left school. They destroyed superstition, struggled to study, relied on their individual skills, and made the needed contributions to the nation.

#### 5. Engineering cold experiments at an intermediate scale

At about the same time as the small-scale hot experiments, parallel engineering cold experiments were in progress to test and confirm the equipment and instrument control systems.

In late 1964, the Second Ministry of Machine-Building Industry decided to convert an idle plant building at the Dalian Machine Manufacturing Plant into an expanded cold laboratory for the extraction process (and placed it under the Design Academy). A complete set of equipment and matching instruments at a scale similar to the pilot plant which was to be built was installed there and non-irradiated cold uranium elements were used according to actual expected conditions to conduct several simulated operating trials and solve problems as they appeared during the experiment. The large number of personnel in the Design Academy and reprocessing plant working in coordination with a few personnel at Qinghua University obtained a rich perception which played an extremely important role in smooth realization of the pilot plant project.

To make full use of Qinghua University's advantages in research on extraction equipment, while the university was building a hot chemical laboratory, it also was rebuilding a cold experimental shop with a daily processing capacity of 30 kg of uranium. In 1965, the first combined operation experimental extraction cycle using three compound clarification tanks was carried out there, and the related automatic control systems were debugged.

In addition, experiments on corrosion resistance in materials and coatings were being carried out at the same time at the Beijing Reactor Engineering Institute. The Changchun Applied Chemistry Institute studied four-valence uranium reduction for plutonium re-extraction, solvent emulsification, and other topics. The Shanghai Organic Chemistry Institute did research on solvents, diluent irradiation decomposition, and solvent emulsification. The Design Academy cooperated with the relevant manufacturing plants in a large amount of work to develop specialized equipment and instruments.

Rich experience was gained during the cold and hot experiments, and the decision to use the extraction method was proven to be both correct and timely. A large amount of experimental data became a reliable foundation for design, and China for the first time extracted about 200 grams of nuclear pure plutonium dioxide product which provided timely raw materials for experiments in key attacks on plutonium reduction metallurgy. This speeded up development of nuclear weapons using plutonium as a partial charge in China.

Through the experience gained in this stage, China's technical staffs working on reprocessing research, design, education, and industrial operations began to grow. Some of them were experts and scholars from the older generation who played a role in leadership and organization, such as Wang Dexi, Cao Benxi [2580 2609 3588], Jiang Shengjie, Wang Jiading, and Ke Youzhi [2688 0645 0037]. Others were middle-aged S&T workers with rich experience in practical work, but most were in the large group of young S&T personnel working at the front line. Most of them later became a technical backbone force for China's reprocessing industry and they have played important roles in China's nuclear industry.

#### Section 4. Research on Fuel Reprocessing for Power Reactors [pp 239-255]

##### [Text] 1. New situation and new task

Irradiated fuel has been removed from China's nuclear submarine power reactors, high flux engineering experimental reactors, and certain other research reactors, and it has been predicted that nuclear power plants will begin unloading fuel in the early 1990's. By the end of this century, we will have accumulated a significant amount of irradiated fuel.

The fuel from the reactors just mentioned can be divided into two main categories based on differences in uranium-235 concentrations. One is "low-concentration uranium fuel" with a uranium-235 content of less than 5 percent used in submarine power reactors, light water reactors at nuclear power plants, and some research reactors. The other is "high-concentration uranium fuel" with a uranium-235 content of 90 percent used in high-flux engineering experimental reactors. Compared to the natural uranium fuel used in production reactors, these fuels have different characteristics after being irradiated in a reactor which in turn greatly affect reprocessing techniques.

There are three main problems with low-concentration uranium fuels: (1) They have different front-end processes. Because the casings of the fuel elements are made of an extremely hard-to-dissolve zirconium alloy, a combined mechanical-chemical method usually is employed to avoid creating waste liquid which is difficult to process. This is the breaking-immersed extraction method, and it is substantially different from the simple chemical method dissolution. (2) They are highly radioactive. Because burning is more extensive in power reactor fuels, there is an obvious increase in radioactive proportions when unloading the fuel. To avoid damage to the solvent by excessive irradiation, the element cooling period can be lengthened, and a pulse sieve plate column should be used as the main extraction equipment because of the rather short time in which the fuel remains in contact with it. (3) A high plutonium content. The plutonium content of power reactor elements usually is more than ten times greater than those from a production reactor. To assure critical safety of the fissionable materials, measures can be adopted to control the geometric shape of the equipment, to control soluble neutron poisons or solid neutron poisons, to control the quality and concentration of fissionable materials, and so on. There also are problems in uranium/plutonium separation and in the plutonium technology chemistry themselves.

For highly enriched uranium fuels, the first requirement is concern for safety by adopting a series of measures from the start of reprocessing. The casings are an aluminum alloy and the cores are a uranium-aluminum alloy, so the uranium concentration is very low because the liquid material after dissolving is controlled by the degree of saturation of the aluminum ions. A dilute tri-ester phosphate extraction process usually is employed. Moreover, plutonium usually is not recovered in the process, so it is rather simple.

## 2. Being ready beforehand

China's reprocessing workers began working in the early 1970's to deal with the task of processing these new fuels. While scientific research was being carried out on all types of special topics, the Design Academy established a Chemical Industry Institute in the late 1970's which could conduct comprehensive experiments on reprocessing and on a plan design and technical program design for a multi-purpose pilot plant capable of processing these fuels.

Over the past decade and more, the masses of S&T workers have worked hard in this area and completed work ahead of schedule. They fostered the old tradition of arduous struggle and arranged attacks on hundreds of key scientific research topics despite the state's limited financial resources. Most projects focused on new goals in the development of reprocessing technologies in foreign countries. Gratifying achievements have been made in many projects through close cooperation by all scientific research departments, institutions of higher education, and production plants, and they provide a definite technical reserve for future intensive development.

In the area of low-concentration fuel reprocessing, attacks had to be made on two key pieces of equipment--the element shearing machine and the pulse extraction column. Given the extremely limited reference data from foreign countries, the Design Academy began working on its own to develop a shearing machine in the early 1970's. After experiments on principles, they designed and developed a horizontal shearing machine with a shearing force of 250 tons. Moreover, carbon steel and zirconium-2 alloy ceramic core simulated elements were used for experiments and observations on knives, fuel transport, breaking, fuel dumping, casing removal, and other questions. Then, they examined more advanced modified equipment and completed design charts for a vertical shearing machine with a daily processing capacity of as much as 400 kg of uranium. Research on the pulse extraction column was conducted mainly by Qinghua University in cooperation with the Design Academy. Beginning in 1978, they made improvements in the mass transfer and hydrodynamic properties of the uranium and nitric acid, in methods for simulated boundary contaminant accumulation and removal in the joint decontamination columns, and in research on cross-section extraction columns, laws of extraction column amplification, and other scientific research topics. Experiments on joint operation and automatic control of a single pulse extraction column and a first extraction cycle (three columns) were done at Dalian. Single-stage and multistage ring-gap centrifugal extractors with even shorter contact times also were explored.

Artificially synthesized simulated liquid material was used for precise test tube tandem simulated countercurrent extraction experiments related to the main technical processes involved in power reactor fuel reprocessing, and rather good technical conditions were explored. To reduce solid waste material during processing to a minimum and save on processing costs, research on the technical chemical process focused on development of a "no-salt process." Projects at the Institute of Atomic Energy attained definite levels in electrolytic reduction for uranium/plutonium separation, electrolytic

oxidation reduction to readjust the valence state of plutonium, continuous precipitation roasting of a nitric acid and plutonium solution, and other topics. Achievements also were made in element immersion extraction, liquid filtering, photochemical processes, denitrification of a nitric acid uranium acyl solution, orthoparaffin diluent screening, large aperture resin purification of used solvent, neptunium extraction chemistry behavior, comprehensive extraction of fission products from waste liquid, neptunium and other trans-plutonium elements, and other research topics.

Many countries have undertaken new research topics on reprocessing technologies for uranium dioxide fuels from light water power reactors, and most have been studied to varying degrees within China. There also are certain other topics like research on the shape of insoluble dregs in the fuel solution, the use of pulse extraction columns to purify plutonium, joint uranium/plutonium processing, and so on. Other topics have not been pursued due to the temporary lack of experimental conditions in China or because they are not suited to China's national conditions.

In the area of engineering research and design, experiments on the use of steam jet and air lifting methods to transport the liquid have been successful. They would permit the elimination of most pumps and valves in future reprocessing plants which would reduce the chances of leakage and the amount of maintenance required. In the area of plant maintenance patterns, progress also has been made in numerical simulation and computer control for process optimization during reprocessing.

In the area of processing highly-enriched uranium fuels, the Institute of Atomic Energy and Fudan University conducted laboratory research on processing technologies between 1976 and 1979 in cooperation with the Design Academy, including experiments on element dissolution, test tube tandem simulated countercurrent extraction, and other topics. Afterwards, cold uranium continuous dissolution experiments were conducted at a pilot plant scale (processing 1 kg of uranium per day) at Dalian.

In addition, China has studied reprocessing techniques for thorium elements and fluoride volatilization to process light water reactor elements.

To permit timely exchanges of scientific research achievements in reprocessing low and high concentration uranium fuels and operational experiences in military reprocessing plants, the Second Ministry of Machine-Building Industry held topical conferences at Qinhuangdao in 1974 and Qingdao in 1977. After the meetings, the treatises were edited and published in a collection. A total of 44 articles were published. Afterwards, scientific research theses and work reports related to reprocessing were presented and published at symposia held by the China Chemistry Society's Radiation Chemistry Sub-Conference and the China Nuclear Society's Radiation Chemistry Industry Sub-Conference. This work laid an excellent foundation for building a multi-purpose reprocessing pilot plant and commercial reprocessing plant in China.

After nearly 20 years of growth China's reprocessing industry has begun to take shape. We have accumulated rich experience in scientific research, design, capital construction, installation, production, and operational management related to reprocessing. This is particularly true of a technical staff which has a definite level. By making full use of these favorable conditions and unremitting efforts, it is entirely possible to complete China's power reactor element reprocessing plant to meet the needs for nuclear electric power, nuclear heating, and nuclear power in China.

## Chapter 12. Production of Thermonuclear Materials [pp 244-255]

### 1. Overview

Thermonuclear materials (also called fusion nuclear fuels) are materials capable of producing a thermonuclear reaction (also called a fusion reaction). Applications for thermonuclear materials through the mid-1980's have been limited to thermonuclear weapons. The main thermonuclear materials are deuterium, tritium, and lithium-6, produced by neutron bombardment of tritium.

A deuterium-tritium reaction is the easiest thermonuclear reaction to achieve, and it releases large amounts of energy. Deuterium and tritium exist in a gaseous state at normal temperatures, however, so they are not suited to the tactical needs of a hydrogen bomb charge. Thus, in real applications they usually are mixed with lithium-6 to form a solid compound like lithium-6 deuterate, lithium-6 tritium deuterate, and so on. Detonation of an atomic bomb, which is the triggering bomb for a hydrogen bomb, produces a large number of neutrons. These neutrons undergo a nuclear reaction with the lithium-6 in the lithium-6 tritium deuterate to form tritium, which triggers a series of thermonuclear reactions that release enormous amounts of energy.

There are two isotopes of natural lithium, lithium-6 and lithium-7. Lithium-6 occurs at an abundance of 7.5 percent (atomic ratio). There are many ways to separate lithium-6 and lithium-7 from lithium, but the chemical exchange method is the only one of industrial importance.

The traditional name for deuterium is heavy hydrogen. It is a stable isotope of hydrogen which can be produced by electrolysis of heavy water. Isotope separation can be used to extract the heavy water in natural water. Tritium is a radioactive isotope of hydrogen. It has a half life of 12.46 years and because it is very scarce in nature, it is produced by extraction via artificial methods.

Preparatory planning for thermonuclear materials production in China began in the mid-1950's. Work began in 1958 to build lithium isotope separation and lithium-6 deuterate production lines. Trial production was carried out in September 1964 and formal operation began in September 1965. This success enabled China to carry out nuclear experiments using thermonuclear materials just 19 months after its first nuclear test. China's first tritium preparation laboratory was completed in early 1963, shortly after construction of the



lithium-6 deuterate production line began. On this basis, construction of the tritium production line began in mid-1966 and products were produced in May 1968. This indicated that China had built a rather complete thermonuclear materials production system. During the 20-plus years since then, there have been new developments in thermonuclear materials production in China. The variety of products has grown, product quantity and quality have improved substantially, and new technical levels have been attained.

## Section 2. Construction of the lithium-6 deuterate production line

### 1. Starting point of construction

China's lithium-6 deuterate production line is composed of several components for lithium isotope separation, electrolysis of deuterium from heavy water, synthesis of lithium-6 deuterate, and other purposes. A chemical exchange method is used for lithium isotope separation. The technical process uses electrolysis to make a lithium-mercury agent. By allowing the lithium-mercury agent and lithium salt solution to pass through the exchange tower as countercurrents to one another, the lithium isotopes in the two phases undergo a chemical exchange reaction which concentrates the lithium-6.

Construction of this production line was begun with assistance from the Soviet Union. In August 1958, preliminary designs supplied by the Soviets were examined in detail and answered in Beijing. Jiang Shushan [5592 6615 0810] and other technical personnel participated on behalf of China. In September 1957, the Nuclear Engineering Research and Design Academy in the Second Ministry of Machine-Building Industry began preparing designs for construction. The many engineering and technical personnel responsible for the design tasks worked constantly, struggling day and night, and completed design tasks for project technologies, civil engineering, electrical instruments, ventilation, water supplies and drainage, and some non-standard special-purpose equipment in just 60 days, 1 year ahead of schedule. This was a good technical preparation for capital construction and it created the conditions for importing equipment ahead of schedule.

Civil engineering construction began as soon as the designs for construction were finished. At the time, it was almost the dead of winter and cold winds from beyond the Great Wall froze the ground. To strive for time and speed up the pace, the construction workers broke with convention and excavated the foundation by heating and removing the ground layer by layer to assure project progress. The civil engineering projects were basically finished by 1960. In May 1959, some 40 cadres and workers including Wang Shiming [3769 0013 2494] organized a lithium-6 deuterate production ship and began preparing for production technologies. In September 1959, 10-odd people including Jiang Shushan went to the Soviet Union for production training.

Just at the time when the project was progressing rapidly, the Soviet cutoff caused major problems in project construction. The main thing was that the imported equipment was incomplete and China was not capable of producing some of the missing equipment at the time. Many theoretical questions and much

basic data on the project still were not fully understood and most work involved feeling our way from the start. To deal with these problems, the Second Ministry of Machine-Building Industry organized its scientific research forces and production personnel to begin basic scientific research and attack key technical problems. They also organized cooperation outside the ministry to find ways to solve equipment manufacturing problems, base construction of the lithium-6 deuterate production line on China's own forces, and continue to move forward.

## 2. Testing of technology and trial production of devices

The CAS Institute of Atomic Energy studied light isotope separation in the early 1960's. After the Soviet experts left, the Second Ministry of Machine-Building Industry decided to concentrate forces to attack key problems. They transferred radiation chemistry expert Liu Yunbin from the Institute of Atomic Energy and several S&T personnel from the light isotope separation topical group to the production plant. In addition, they chose several engineering and technical personnel and assigned a group of college graduates to fill out the scientific research forces in the plant. To gain a basic understanding of the technologies, they spent 1 month in early 1962 in full analysis and dissection of the project focused on problems and not-yet-understood questions which might appear during industrial production, and they made arrangements for 95 research topics. In May 1962, they established the Lithium Isotope Research Office with Liu Yunbin as director. Based on the topics which had been arranged, they established four research groups for physical chemistry, technical experiments, theoretical calculations, and analytical methods, and began comprehensive attacks on key technical problems.

These S&T personnel were deeply aware of the importance of the problems they had to solve in the overall plan for nuclear weapons. With a strong sense of political responsibility, they threw themselves wholeheartedly into solid theoretical and experimental research. For example, the chemical exchange tower was a large cascade system, and computations were necessary to find the optimum operational program. However, the Soviets had supplied only summary data at the time and we were unfamiliar with calculation methods. To examine and confirm the design and guide production, a theoretical calculation group composed of Zhou Xiuming [0719 0208 6900] and others and assisted by the Computer Office at the Institute of Atomic Energy first of all studied isotope enrichment equations and eventually discovered stable and non-stable formulas. After dealing with computation methods, they modelled the isotope enrichment process in the exchange tower, chemical exchange system output rates, and effects of operational parameters on output rates, startup equilibrium periods, feeding programs for the startup process, and so on. They made rather complete calculations and provided a large amount of useful data to guide future production.

Another example is lithium-mercury agent, one of the primary media of chemical exchange. It is prone to self-decomposition, and lithium-6 isotope enrichment is severely affected if decomposition proceeds too quickly. The relevant S&T personnel conducted several experiments focused on the role of



various materials in mercury agent decomposition and on temperature effects to explore the factors which affect decomposition. They studied the effects of single materials and explored the combined effects of various combinations of elements to gain an understanding of the laws of self-decomposition in the lithium-mercury agent.

After more than a year of hard work, they also measured the physiochemical properties of mercury and the separation coefficients of a lithium-mercury agent--lithium salt solution system assisted by the Institute of Atomic Energy, Beijing University, Qinghua University, and other units. They examined, confirmed, and supplemented the preliminary design and formulated a feeding program. They also established various analytical methods. Through timely summarization, they provided 18 scientific research achievement reports and compiled technical regulations, operational methods, and other technical laws and regulations. This laid a solid foundation for feeding and trial production and it trained several backbone technicians.

At the same time, major support was provided by many units throughout China in supplies of the needed materials and equipment, and in manufacture of instruments and devices.

In the area of separation technologies, the fact that the volume pumps used to transport the materials were easily abraded meant that large numbers of them were needed each year. The Shenyang Water Pump Plant and other related units organized manpower in the early 1960's for trial manufacture and achieved success before operation of the lithium-6 production line, which guaranteed startup and continuous production. Afterwards, new pump models were manufactured on a trial basis.

The mercury cathode electrolysis tank was an important piece of production equipment. The relevant units spent 3 years solving key technical problems like nickel-nickel and nickel-steel welding, aluminum extrusion, and so on, and in the end they manufactured products meeting specifications.

In addition, relevant units across China successfully manufactured vacuum valves, electromagnetic flow meters, alkaline concentration meters, and other instruments and equipment. The Ministry of Chemical Industry provided timely supplies of heavy water to make deuterium and the Ministry of Metallurgical Industry provided lithium salt raw materials. These were important contributions to the timely operation of the lithium-6 deuterate production line.

### 3. Installation and adjustment, training of personnel

Equipment installation and debugging began in early 1961. Many problems were encountered in this work.

Lithium isotope separation systems placed very high demands on degree of vacuum, purity, and precision in equipment installation. No ready-made data was available and there were no complete sets of equipment. Engineering and technical personnel and workers had to combine practice with exploration to solve problems one after another.

To assure a high degree of purity in the pipelines, they had to be cleaned meticulously after they were installed. Cleaning large numbers of pipe bends processed with a poured sand hot bending method was no easy task. To assure that no sand got into the system, the workmen thought of methods and eventually cleaned the bends until they were spotless.

Exchange tower verticality and the precision of redistributor installation have extremely sensitive effects on separation results. To adjust the verticality, technician Li Xiangrong [2621 0686 2837] and others made repeated explorations and created a complete set of coordinated measurement and installation tools to bring the verticality of the exchange tower to within less than 2 parts in 10,000, so redistributor installation conformed completely to requirements. The mercury cathode electrolysis tank had to be readjusted until it was certain the tank was level horizontally. Moreover, a specific vertical slope was required and the many electrolysis tanks in each group had to be in the same state. At times, to attain the parameters of a single state, the operating personnel made spent hours making repeated measurements and readjustments until the demands were met. Due to the careful attention to detail and arduous efforts by installation and debugging personnel, precision requirements were met in all aspects of equipment installation and an excellent foundation was laid for operational startup.

Technical training for production personnel was an important link to assure successful operation. Most in China's first group of lithium-6 deuterate production personnel were transferred from other industries. They felt a strong sense of responsibility and combined study and work in practice. During equipment installation and debugging, for instance, the operational personnel studied basic theory and graphic data to understand technical processes, equipment performance and structure, and so on. These activities were called "technical soundings" at the time. As the time for operation neared, training work shifted to training in operation methods. Many activities were used to train frontline troops: "discussing operational guidelines," which mainly involved graphic activities, some "training troops at their posts" for operational training in positions, "accident drills" for handling imaginary accidents, and so on. During operational training, it was quite common to develop inspection and emulation as well as single item operations contests and mutual assistance, mutual study activities. Several skilled operators appeared within the shops. During operations to regulate the flow rate of materials, for example, some people achieved successful regulation on the first try. To assure "mastery and trustworthiness" in the positions, the workshops organized a testing committee for oral and writing examinations of qualified candidates who either received "qualification certificates" or were not allowed to take up the positions.

The strict training created a workforce with technical mastery. They were not merely remarkable in completing their tasks in future production. Many of them also became skilled in technical innovation. An example is Wang Juchun [3769 1565 2504], who suggested a method for controlling liquid level operations which reversed a situation in early production in which liquid levels could not be controlled and the system was hard to stabilize, thereby solving a major problem in production.

By the end of 1963, all personnel in the plant had received strict training and all personnel were prepared for startup and operation.

#### 4. Going into production

At the time, this facility was China's "only child." If not fully understood, we dared not start it up rashly. Moreover, some control parameters in the lithium isotope separation system still had not been examined and confirmed, and there was some basic data that could be measured only in technical facilities. For this reason, equipment was organized in early 1964 for a small-scale simulation facility, but the process was greatly simplified. This facility was used to measure the characteristic data for filling and fluid experiment data for the exchange tower. They observed decomposition of the lithium-mercury agent in the filling layer, and the measured decomposition data conformed to laboratory decomposition experiments. Later, they obtained lithium-6 product samples at fairly low concentrations. It was confirmed that the large-scale facility could produce lithium-6 products at definite concentrations, which greatly encouraged all of the employees.

After the small-scale experiments, preparations also were made, for the sake of caution, to build an intermediate-scale experiment facility. The Second Ministry of Machine Building Industry held an engineering conference from 2 to 19 March 1964 at the production plant site to examine and accept achievements made in work during the early stages and to arrange the next steps. Besides plant leaders and technical personnel, several experts from inside and outside the ministry also participated in the conference. Under the direction of Nuclear Fuels Bureau Chief Engineer Cao Benxi, the conference examined and approved 33 analysis and inspection programs and 13 scientific research reports. They discussed and evaluated the required conditions for startup of the production facility and the amount of work needed to prepare for production. They also held earnest discussions on work arrangements for the next step. This conference played a positive role in speeding up construction of the production line. After the conference, they did intermediate testing and began work to prepare for trial startup of the production facility.

On 9 June 1964, trial production got underway. Partial linkups of the facility to test each item in the process began on 18 July. The goal was to test the links and level of synchronization of each procedure, to examine the feasibility of each operational parameter, and to determine the reliability of operating parameters. After 10 days of trial operation, lithium-6 products at a 40.2 percent concentration were obtained, so the trial operation was successful. It showed that the day was near when products meeting specifications could be obtained. On 21 August 1964, construction of the lithium isotope separation facility was approved. Testing of the fully-connected facility began on 3 September and the first group of military lithium-6 products was produced 14 days later, on 17 September. Some time after trial production, a brief overhaul was done to make readjustments and improvements in the equipment and operations to facilitate formal production later.

While victories were being reported at the lithium-6 production line, substantial progress also was being made in all processes in the later stages.

Testing of the heavy water electrolysis tank used in the deuterium manufacturing process showed the product did not meet purity standards. The scientific research personnel made their own designs and produced a trial Chinese-made electrolysis tank. After being tried out, it performed excellently and the oxygen content of the deuterium gas it produced was held at a very low level. To make good preparations prior to production, several years were spent in a major effort to explore the production conditions of synthesis processes. Several trial varieties were manufactured to determine crucible materials, and one eventually was chosen for use in production.

In June 1964, after all of the processes in the end stage had been cleaned and tested, they went into trial production. The first group of lithium-6 deuterate products which conformed to specifications was removed from the furnace on 23 September, substantially ahead of the original schedule. This indicated that China now had the capacity to produce lithium-6 deuterate. This production line provided thermonuclear materials for China's blast tests of atomic bombs containing thermonuclear materials and the first hydrogen bomb blast test, so it contributed to the development of nuclear weapons in China.

### Section 3. Development of production line for lithium-6 deuterate

#### 1. Improving technology and raising the efficiency and benefit

China's first lithium-6 deuterate production line was designed in the late 1950's. The equipment involved many manual operations, consumed large amounts of energy, had backward control instruments, and was prone to operating accidents. S&T personnel at the plant made several reforms in technology, equipment, instruments, and other areas on the basis of complete digestion and understanding of this technology and production developed continually as a result.

They began first of all to prepare for planning a control room in the early 1970's. After 2 years of survey research and technical preparation, the design was completed. They also spent 2 years to finish construction, installation, and debugging, establish an automatic regulation system, update several monitoring instruments, install several new remote instruments and remote control facilities, and transform electrical control systems. In addition, material pipelines were simplified and valves were updated. After refitting of the control room, the operation personnel no longer had to stand in front of the equipment, continually monitoring and adjusting as they did in the early stages of production. Instead, they could carry out remote control from the control room.

Filling performance of the exchange tower was a key factor which directly affected the separation effects of chemical exchange. To increase unit hourly output of the lithium-6 production stage, conversion starting in October 1976 focused on selection and trial manufacture of new fillers. Led by Engineer Jiang Shushan, the scientific research personnel conducted filling experiments with materials of many varieties and specifications. On this

basis and through complete survey research, they proposed a new type of filling in 1977. After design and processing, tower installation experiments began in 1978. Based on testing in actual operation, one complete set of equipment chosen from two types of specifications was used in 1979. The result was new records in unit hourly output, monthly output, and several other economic and technical indices. From 1980 on, the old type of filling was totally abandoned and output increased after the new type of filling was adopted. Moreover, unprecedented economic and technical indices were attained. Two more improvements were made in 1982 and 1983, and the design was finalized in 1984. High-efficiency industrial feeding was developed through 7 years of experimentation and it increased material throughput by 30 percent. The contour plate elevation declined by 35 percent, which reduced the overall height of the filling layer and reduced the number of exchange towers and pumps. Production was more stable after this type of filling was adopted and there was an obvious reduction in accidents. This achievement received an award from the National Defense Science, Technology, and Industry Commission.

Many improvements were being made at the same time in other processes, including metallic lithium refining, deuterium gas purification, feeding patterns for synthetic lithium deuterate, and so on. This made the overall production technology even more rational. In addition, high purity lithium-7 and calcium hydride were produced.

Besides the technologies outlined above, they also did much work focused on reducing energy consumption and improving management standards. Just two of the items, a shift to cycling the cooling water and a reduction of two freezing units, saved about 400,000 yuan each year. Microcomputers began to enter the realm of plant management in 1981. After completing a cascade theory computing software package, microcomputers were used to make optimal computations for startup programs. They guided startup in 1984 and 1985 and provided rather good economic results.

## 2. Treatment of mercury contamination

Lithium-6 production creates a lot of the three wastes [waste gas, waste water, and industrial residue] which contain mercury. Procedures to deal with the three wastes in the original design used a manganese dioxide adsorption method for the mercury-contaminated gas and two-stage processing of mercury-contaminated water which involved precipitation and sulfonated coal. The results were rather poor. Thus, handling the "three wastes" became an important research topic not long after it went into production.

In the three material states of mercury, the largest amount was in waste water containing mercury and the range of contamination was widest. Moreover, the process of dealing with the other two material states created waste water. As a result, processing mercury-contaminated water was a major aspect of controlling mercury contamination. In 1974, in conjunction with the experiences of other units in China, the technical personnel in the shop designed a mercury waste processing technique involving swirl separation--natural precipitation--activated charcoal adsorption. After repeated

experiments, the swirl separation step was eliminated. After simplification of flow process, it went back into production in February 1979. Within a short period of time waste water discharges met state public health standards, and the results were rather satisfying. However, because the problem of re-processing the activated charcoal had not been solved, the design for this technology could not be finalized. On the basis of 2 years of operating experience, engineer He Liyi [0149 4539 5030] went further and proposed a technical program involving a concrete precipitation--mud acidification method. Trial operation began in March 1980 and formal operation got underway in July. The mercury content of the waste water attained state discharge standards and the mercury removal rate exceeded 99 percent. The results showed that this technical flow process had many advantages in that re-use of the mud acidification could reduce the amount of mud by 80 percent. It can adapt to changes in water quality like turbidity, mercury content, acidity or alkalinity, mercury state, and other aspects. To prevent the effects of variations in technical water discharges during operation, two water tanks were rebuilt in 1984 to further improved this process.

Under overall plan arrangements, preparations began in 1983 for a project for separation of purified and contaminated flows. This project include re-arranging the surrounding water system, levelling the land around the plant building, work time readjustments, and other projects. Construction of the project for separation of pure and contaminated flows indicated that a new stage had been entered in mercury contamination control work.

Work to reduce the mercury content of the air inside the plant building was extremely difficult. As a result, the plant proposed principles for comprehensive control. They first spent 2 years studying mercury consumption equilibrium and measuring the direction of mercury bleeding. At the same time, they measured the mercury content of the air in the plant building, compiled an atmospheric mercury distribution chart, and manufactured a portable mercury detector. To make accurate measurements of the system mercury content during operation and precise computation of mercury consumption, the plant cooperated with the Institute of Atomic Energy in 1983 for research on a mercury-197 isotope dilution method. In addition, they also did a considerable amount of work to improve operations and equipment, reinforce responsibility system management, and other things. After several years of effort, the mercury content of the air in the plant building was reduced substantially, almost to the normal levels prior to plant startup. This produced a fundamental improvement in the working conditions of the employees.

## Section 2. Nuclear Physics Research [pp 365-387]

The new discipline of atomic and nuclear physics emerged during the 20th century, and through it mankind has made intensive explorations into the structure and laws of movement and change of atomic nuclei. Before New China was founded, only a few scattered individuals in China were conducting research in this area. Following the establishment of New China, the Modern Physics Institute was organized in 1950, and it was on this plot of land that



research on nuclear physics began in China. After 1955, in addition to the Institute of Atomic Energy, the Shanghai Institute of Atomic and Nuclear Research, and the Lanzhou Modern Physics Institute, units engaged in nuclear physics research included universities with physics majors like Beijing University, Qinghua University, Jilin University, China University of Science and Technology, Fudan University, Nanjing University, Lanzhou University, and others. The High-Energy Physics Institute was established in 1973. The Low-Energy Physics Institute at Beijing Normal University and the Institute of Nuclear Science and Technology at Sichuan University were built during the late 1970's. There also were quite a few people working on nuclear theory scattered in several universities and other departments. Nuclear physics research staffs have grown continually and made outstanding achievements in the past 35 years.

#### 1. Tasks in solving the key technical problems with the atomic bomb and hydrogen bomb

Through arduous pioneering work during the 1950's, nuclear-physics research in China has made definite technical preparations. The key moment in China's self-reliance in building a nuclear industry came in 1960. During that period, several talented people, including Wang Ganchang, Peng Huanwu, Zhu Guangya [2612 0342 0068], Deng Jiaxian, Cheng Kaijia [4453 7030 3946], Zhou Guangzhao [0719 0342 0664], Yu Min [0060 2404], Huang Zuqia [7806 4371 3174], and others, participated directly in nuclear weapons development and made noteworthy achievements. In addition, physicists at the Institute of Atomic Energy, the Lanzhou Modern Physics Institute, and other related research units and universities shifted the focus of their research toward assuring solutions to key problems with the atomic and hydrogen bombs.

(1) In 1960, the Institute of Atomic Energy and other units clearly measured the neutron cross sections of heavy nuclei, the energy spectra of fission neutrons, and average values for fission neutrons related to fission reactions, and they established various radioactivity measurement methods and standards, including neutron-flux standards, neutron-source intensity standards, alpha-source intensity demarcations, and so on. While processing some of the components used in the atomic bomb, the institute participated in some inspections and worked in conjunction with the nuclear test site to establish measurement methods for neutron flux, neutron energy spectra, gamma pulses, and so on. During measurement of burnup in nuclear explosions, it assumed responsibility for setting up numerical measurement methods for fission and other areas. All of this contributed in varying degrees to China's first nuclear test.

(2) In December 1960, while the Beijing Institute of Nuclear Weapons was busy developing the first atomic bomb, Minister Liu Jie of the Second Ministry of Machine-Building Industry arranged for the first step in exploring the principles of the hydrogen bomb at the Institute of Atomic Energy. He organized the Light Nuclei Reaction Device Theoretical Exploration Group under the direct leadership of institute director Qian Sanqiang. The group had a total of 20 key personnel in the areas of theory and

mathematics. Huang Zuqia and then Yu Min served as group leader. Most of its personnel were assigned to the Beijing Institute of Nuclear Weapons in February 1965 to concentrate forces for breakthroughs in hydrogen bomb development. For more than 4 years, the group worked mainly in two areas: (1) exploration and research on the various physical processes in the hydrogen bomb; and (2) explorations of the principles and structure of hydrogen bomb action. Although these probes and studies were not fully mature at the time, they did suggest several ideas and prepared the relevant equations and data, so they played a role in taking the first step and exploring paths.

In 1960, the Light Nuclei Reaction Group was set up in the Institute of Atomic Energy with Ding Dazhao [0002 1129 0664] as group leader. It conducted survey research on light-nuclei reaction cross section data, and it made some experimental preparations and developed work on measurement of light nuclei reactions.

In early 1965, during the process of developing the hydrogen bomb, the Beijing Institute of Nuclear Weapons had an urgent need for data on deuterium and lithium reaction cross sections. On 13 February, Vice Minister Liu Xiyao assigned the task of measuring deuterium and lithium-6 cross sections to the Institute of Atomic Energy and called for its qualitative and quantitative completion during the first half of 1965. This task was technically difficult and time was pressing, so the Institute of Atomic Energy concentrated forces for a war of annihilation. It transferred 30 key professionals (later expanded to 50) from various research offices to organize a shock brigade under the professional leadership of institute deputy director He Zehui [0149 3419 1979] to take up the work quickly. To make the fullest use of existing large equipment, management of the institute's single accelerator and three multichannel analyzers was centralized for a full effort to coordinate with experimental work. The task was completed in less than 6 months. This clarified discrepancies with foreign data and played an important role in selection of a program for hydrogen bomb development in China. Next, rather systematic measurements were made of light nuclei reactions, including deuterium-deuterium and deuterium-tritium reaction cross sections, and the various reaction channels of the interactions of deuterium-lithium (including lithium-6 and lithium-7), thus providing a complete set of reliable data for nuclear weapons development.

During the same period, the Lanzhou Modern Physics Institute and the Shanghai Institute of Atomic Energy also showed exemplary performance in completing some projects on cross-section measurements of light nuclei reactions.

(3) In the area of theoretical computations, the Institute of Atomic Energy completed several projects associated with nuclear weapons development, nuclear testing, and nuclear industry construction, including theoretical calculations for fast criticality devices, the Monte Carlo method for theoretical computations of particle transport questions, theoretical computations on uranium isotope and lithium isotope separation cascades, critical safety computations, reactor theory computations, and so on.



## 2. Nuclear data

Nuclear data refers to various physical quantities associated with the properties of atomic nuclei and the laws of interaction between various rays and atomic nuclei. Examples include the quality, magnetic moment, mode of decay, reaction cross section, categories of reaction products, yield, energy spectra and angular distribution, and so on. It is an important aspect of the direct service of nuclear physics research to the nuclear industry. Accurate and complete nuclear data is the basic foundation for design of all types of equipment and for on-site testing and analysis. It also is required for the nuclear technologies used in industrial, agricultura, medical, and other sectors.

During the 1960's, fragmentary measurements were made of some important nuclear data for the purposes of nuclear weapons development and submarine nuclear powerplant design. In the early 1970's, as nuclear technologies in China developed and international nuclear data expanded, it became apparent that China's original nuclear data had become outdated and that improvements and reinforcement were necessary. Under the unified leadership of the Second Ministry of Machine-Building Industry, and with motivation and concrete organization by Li Shounan [2621 1108 2809], most nuclear physics research forces from throughout China systematically undertook work for compilation and evaluation of nuclear data, theoretical computations, and measurements. In 1975, the China Nuclear Data Center was formally established to organize a cooperation network with 13 participating units. It gradually was expanded later to include 26 units.<sup>1</sup> The measurement, compilation, and evaluation of nuclear data stabilized staffs, trained cadres, and motivated scientific developments. Their primary achievements include:

The first major achievement was the completion of a complete neutron nuclear data evaluation for 36 key nuclear elements (including all reaction channels). A computerized nuclear data base was established on the basis of internationally accepted specifications: the China Evaluation Nuclear Data Base Volume 1 (CENDL-1). Other achievements include: evaluative data bases for the specially determined reaction channel excitation curves of about 30 types of indicator nuclear elements and excitation curves for 19 charged particle reactions; yield data on more than 200 products of monoenergetic neutrons and fission-spectra neutron-induced uranium-235, uranium-238, and plutonium-239 fission; data on the decay of 169 nuclear elements, and an evaluation of resonance parameters for 97 nuclear elements.

With the exception of a portion which depend primarily on experimental data or are supplemented with experimental data, theoretical computations must serve as the basis for the creation of a complete set of evaluative nuclear data. For this reason, the Nuclear Data Center comprehensively examined and used mature international nuclear model theories and methods, and on this foundation it established a computing program which included optical models, H-F statistical theory, exciton models, and so on. Extensive research was conducted on certain relevant theories and quite good progress was made. Group constants and benchmark observations were compiled and a computerized nuclear data base was established.

The overall quality of CENDL-1 approximates the newest international evaluative nuclear data base editions, but the number of nuclear elements is too small and the documentation is incomplete. No covariance documentation or macroscopic examinations have been made. These data in conjunction with data obtained from international contacts can provide preliminary satisfaction of the needs of nuclear engineering.

The second major achievement was that, given the reality in China of too few and inadequately precise principles for nuclear-data measurements, arrangements were made to measure the most important data chosen on the basis of real needs and experimental capabilities.

Under conditions of 1-5, 8, 11, and 13 MeV, measurements were made of elastic and inelastic scattering differential cross sections for deuterium, lithium, beryllium, carbon, iron, molybdenum, nickel, uranium, and other nuclear elements. In addition, the secondary neutron energy spectra (dual differential cross sections) of deuterium and uranium and the gamma generation cross sections and capture spectra of certain nuclear elements were measured at an energy level of 14 MeV. Precise measurements were made of the excitation curves [(n,x), (n,xn), and so on] of more than 30 nuclear elements using activated threshold detectors. Some measurements also were made of charged particle activation reactions using a superimposed target method.

In the area of fission data, systematic measurements were made of the yield of thermal neutrons, fission spectrum neutrons, and monoenergetic fast neutron fission in uranium-235 and uranium-238. Focus was on measuring neutron fission in uranium and plutonium nuclear elements, and the instantaneous neutron count and energy spectrum of spontaneous californium fission. Within a range of thermal neutrons to 15 MeV (minus a few intermediate energy regions), the fission cross sections of six nuclear elements including uranium, plutonium, neptunium, and americium were measured.

Although too little work has been done in the area of nuclear data measurement, most of the results approximate similar experiments in other nations: the methods are similar, and the level of precision is about the same. Some items filled gaps in international data, some clarified discrepancies, and some of the most important ones confirmed the accuracy of published foreign data. Shortcomings included the lack of a large accelerator, incomplete neutron energy regions, lagging experimental measures, and short work schedules.

### 3. Cosmic rays and high-energy physics

In 1954, under the leadership of Wang Ganchang and Xiao Jian [5135 0256], the Physics Institute completed the High Mountain Cosmic Ray Laboratory at Luoxue Shan in Yunnan Province. It utilized a multi-plate cloud chamber and magnetic cloud chamber for research on strange particles and high-energy physics effects. From 1954 to 1957, it collected examples of more than 700 strange particles and made several quite valuable achievements.

In 1956, the Dubna Integrated Atomic and Nuclear Research Institute was established in Moscow. Wang Ganchang, Hu Ning [5170 1337], Zhu Hongyuan [2612 3163 0337], Zhang Wenyu [1728 2429 5940], and other famous scientists and a large group of young Chinese S&T workers participated in work at the institute. Wang Ganchang served as its deputy director. In early 1960, his group used the 10 BeV high-energy accelerator at the institute to discover sigma-bar negative hyperons ( $\bar{\Sigma}^-$ ). This was a major scientific research achievement, and it received a first-place state natural sciences award in China in 1962.

In November 1965, under the leadership of Zhang Wenyu, the Institute of Atomic Energy built a large cloud-chamber facility. This facility was composed of three large cloud chambers, with magnetic cloud chambers 1.7 m tall between them. The magnets weighed 200 tons. The cloud chamber was built on a high mountain at an elevation of 3,222 m at Dongchuan in Yunnan, and it became one of the world's few advanced high mountain cosmic ray laboratories. In 1977, the High-Energy Physics Institute formally completed its High Mountain Emulsion Chamber at an elevation of 5,500 m in the high mountains of Xizang. This is one of the highest points for cosmic ray research in the world. Several very interesting cosmic-ray examples at energies of around  $10^{16}$  eV were obtained during research in the early 1980's.

From 1964 to 1966, based on the philosophical viewpoint of Mao Zedong concerning the infinite divisibility of matter, about 40 people in the Institute of Atomic Energy, Beijing University, the Mathematics Institute, the China University of Science and Technology, and other units under the leadership of Zhu Hongyuan, Hu Ning, He Zuoma [0149 4373 7802], Dai Yuanben [2071 0337 2609] and others suggested a straton model of hadron structure. This achievement reached rather advanced international levels at the time and received a second-place state natural sciences award in 1982.

#### 4. Heavy ion physics

In 1970, the Lanzhou Modern Physics Institute converted its 1.5-meter cyclotron into a heavy ion accelerator for carbon, nitrogen, and oxygen to study synthesis of trans-plutonium elements. It carried out several heavy ion nuclear reaction research projects from 1973 to 1981. It used heavy nuclei containing carbon-12, nitrogen-14, oxygen-16 and other injected particles to cause a reaction and studied light particle emission, fully-fused cross sections, large mass transfer, and other questions. It was discovered and confirmed that there is a mechanism with a rather high probability of creating beryllium-8 group transfer during a carbon-12 and bismuth-209 reaction. Heavy ion reactions were used to synthesize six isotopes of elements 98, 99, and 100. Rapid transfer devices and helium nozzle transfer systems were used for heavy ion reactions to synthesize the neutron-deficient iodine isotopes iodine-116, 117, 118, and 119. Carbon-12 and other heavy ions were used with gold, tungsten, and other heavy nuclei to form light fission nuclei systems for measuring fission channels.

In the theoretical area, the institute carried out computational analysis of the beryllium-8 group transfer reaction, and used diffusion theory and the Monte Carlo method to study deep inelastic collisions.

## 5. Low-energy physics

### (1) Experimental research

In 1950, the Modern Physics Institute began work on creating the conditions for experimental research on low-energy physics. By 1958, the electrostatic accelerator it had developed and built themselves went into operation, and the heavy-water reactor and cyclotron built with Soviet assistance also were turned over for use. After several neutron crystal spectrometers and flying-time spectrometers were built beside the reactor and cyclotron, He Zehui, Zhu Guangya, Dai Chuanzeng [2071 0278 2582] led experimental research in nuclear physics and conducted neutron physics experiments in the heavy-water reactor. Besides neutron physics, they also undertook research at the cyclotron on (d,p) polarization and other nuclear reactions. They conducted research on light nuclei reactions in the mass electrostatic accelerator. After the high-voltage intensifier was completed at the Lanzhou Modern Physics Institute, experimental work on fast-neutron physics and light-nuclei physics in the high-voltage intensifier was conducted. This work made the technical preparations for attacks on key problems with the atomic and hydrogen bombs during the 1960's.

Beginning in 1953, Mei Zhenyue [2734 6966 1471], Zheng Linsheng [6774 2651 3932], and others at the Modern Physics Institute designed and built five  $\beta$  spectrometers: a single lens, a ferrous dual focus, a nonferrous dual focus, an intermediate imaging, and a permanent magnet 180° model. They debugged the  $\beta$  spectrometers between 1956 and 1958. In the 1960's they began to measure large deformed nuclear region energy spectra and modes of decay. After the 1970's, most of the research personnel were shifted to neutron activation analysis, ion beam analysis, Mossbauer spectra, and other applied research.

In 1955, Ding Yu [0002 3254] began building China's first atomic beam device and studied nuclear magnetic resonance (NMR). This provided valuable references for the completion of a cesium-atom standard clock for measurement science and for the extension of applied NMR spectrometers throughout China. After 1976, there were substantial improvements in experimental technologies in low-energy physics in China, and some new-generation nanosecond neutron flying-time spectrometers, germanium gamma spectrometers, and so on were completed. Many types of high resolution semiconductor probes came into common use. Multidimensional measurement data gathering systems and computer applications became more common. Various types of flexible site probes, magnetic spectrometers, helium nozzles, and other advanced experimental equipment became familiar.

In the area of few-body and light-particle nuclear reactions, experimental research was carried out for a small number of nucleon systems. The processes of quasi-free scattering and quasi-free reactions in low-energy regions were observed, and experimental evidence was observed for  $^8\text{Be}$  chain molecule states, which provided information for understanding the group structure of light nuclei. Pre-equilibrium emission mechanisms were observed in an energy region even lower than those in which work was being done in other nations. Rather systematic experimental research was carried out on three-nucleon transfer reactions and large-angle anomalous scattering of alpha particles. Intermediate structures which may exist in low-energy deuterium nuclei and certain light atomic nuclei reactions were observed.

In the area of nuclear decay, precise nuclear spectrographic research was conducted on rare-earth-region large deformation nuclear elements and certain fission product nuclear elements, and modes of decay based on the decay gamma spectrum and coincidence characteristics were established or revised. Experimental research was conducted on beam gamma spectra at several cyclotrons and a group of new spectral lines was discovered which confirmed several new rotation zones. Blocking effects, Doppler displacement, resonance absorption, and other methods were used to measure several types of compound nuclei or nuclear energy level lifespans.

In the area of fission, measurements were made on the half-life of spontaneous-fission-form isomeric-state plutonium-240m, the isomeric cross-section ratio, and its electrical quadrupole moment. The spontaneous-fission properties of uranium-238 and plutonium-240 have been studied, and the fragmentation isotropic heteromorphism of uranium-238 neutron fission have been measured and analyzed. Systematic and precise research was conducted on various post-fragmentation phenomena and the relational characteristics of californium-252 spontaneous fission.

## (2) Theoretical research

In 1950, the main activities were in research on questions related to nuclear forces and few-nucleon systems. In 1953, under the leadership for Peng Huanwu and Zhu Hongyuan, all of the personnel in the Physics Theory Group conducted systematic survey research of documents in atomic and nuclear physics, and this served as a basis for theoretical research on nuclear physics. In 1955, Yu Min published the article "On Some Atomic Nuclei Energy Levels Near Lead-208" and filled in a gap in nuclear-theory research in China. From 1958 to 1960, the research institutes organized under the call for "everyone to become involved in atomic-bomb science" assigned people to the Institute of Atomic Energy to study and work on atomic and nuclear theory (nuclear structure, nuclear reactions, and nuclear fission), which greatly expanded theoretical work staffs. After 1960, some comrades in the Institute of Atomic Energy and other units were shifted into the relevant theoretical computation tasks for development of the Beijing Institute of Nuclear Weapons and the nuclear industry, and they made important contributions.

The Nuclear Data Center was established in 1973. A large portion of nuclear theory workers from throughout China participated in nuclear-data measurement, compilation, and evaluation. Some nuclear theory workers continued basic research work. This work can be divided into two main areas:

(a) Nuclear forces and nuclear structures

Nuclear forces are a basic problem in nuclear theory which has remained unsolved for a long period of time. Recently, people have taken into consideration the internal structure of nucleons during research on interaction between very close nucleons. Theoretical researchers in China studied straton modelling, pocket modelling, solitary-particle modelling, and other topics which were very important directions of exploration. Enormous achievements were made in research on interactive boson modelling (IBM). Boson wave functions and interaction among bosons were studied. While exploring the basis for IBM, in addition to suggesting the two types of s and d bosons, researchers gave consideration to theses concerning g bosons. They also used IBM to describe the phenomenon of "back-bending." In the area of light-nuclei group modelling, they studied quasi-free scattering, quasi-free reactions, quasi-molecular states, and other topics. They used group modelling of wave functions to calculate contortion effects in quasi-free scattering, and obtained excellent results. They studied quasi-molecular states and predicted the existence of Be-8 chain molecular state structure. In the area of many-body theory, the Green function was used to derive the single-particle potential trough, which in turn was used to calculate energy spectra for several light nuclei and improve the degree of fit between theory and experiment. Continuous-medium modelling and mass formulas were used to attain a very high degree of precision. Generator coordinate methods were used to discuss collective movements in atomic nuclei and to study certain properties of atomic nuclei.

(b) Nuclear reactions

Improvements were made in excitation models in the areas of computing pre-equilibrium, and angular distribution of emissions, and other areas, with excellent results in all of them. Research on SKYRME mechanical responsiveness micro-optical potential was used in computation of nucleon-channel cross sections. Research was conducted on non-statistical effects in the mechanisms of low-energy neutron irradiation capture reactions and consideration was given to the effects of giant resonance on low-excitation-state inelastic scattering. The concepts of Brownian movement were used to study fission of atomic nuclei, and the Fokker-Planck equation was used to calculate fission speed. In addition, drip encasement revision, thrust rotation models, and other techniques were used to study questions of fission potential barriers, mass distribution, and viscosity.

Corresponding research on giant resonance, high-spin-state group theory, and other areas was also carried out.



## 6. Intermediate and high-energy physics

Due to the lack of experimental conditions, only a small amount of theoretical work has been done to date. Examples include the use of multiple magnetic collision theory to study interactions between a  $\pi$ -medium and atomic nuclei; and research on the structure of certain peculiar nuclei (also called hypernuclei, or atomic nuclei which contain hyperons). Meson exchange theory and phenomenological theory were used to estimate the interactions between lambda particles and nucleons, and between lambda particles and lambda particles, and they were used to compute the properties of hyperons. Some achievements have been particularly creative.

## Section 3. Research on nuclear chemistry and chemical engineering

Research on nuclear chemistry and chemical engineering refers to research on questions in chemistry and chemical engineering related to the nuclear industry. In 1953, the Modern Physics Institute undertook laboratory research on uranium-ore extraction, heavy-water and graphite preparation, and other problems to develop the materials needed to build a reactor. After construction of China's nuclear industry began, there were corresponding developments in research on nuclear chemistry and chemical engineering. Laboratories were established in the Institute of Atomic Energy for radiation chemistry; analytical chemistry; nuclear fuel reprocessing; development and utilization of radioactive isotopes; handling of radioactive waste liquids, waste water, and industrial residues; uranium isotope separation; and other areas. These laboratories carried out scientific research in the related disciplines. During this period, scholarly leaders at the associate researcher level and above included Yang Chengzong [2799 2110 1350], Guo Tingzhang [6753 2185 4545], Xiao Lun [5135 0243], Feng Xizhang [7458 6932 3864], Liu Yunbin [0491 0336 2430], Liu Jingyi [0491 7234 1355] (concurrent appointment), and others.

After 1960, during attacks on key questions related to the atomic and hydrogen bombs, the research tasks in nuclear chemistry and chemical engineering were extremely numerous. For this reason, the Second Ministry of Machine-Building Industry chose to transfer Wang Dexi [3076 1795 3556], Wu Zhengkai [0702 1767 6963], Cao Benxi [2580 2609 3588], Jiang Shengjie, Chen Guozhen [7115 0948 3791], and others from institutions of higher education, and from chemical engineering, petroleum, and other departments to reinforce leadership over scientific R&D work. Guided by the principle of major cooperative efforts, the CAS, institutions of higher education, and other related units actively participated in attacks on key issues in nuclear chemistry and chemical engineering. During the process of attacking these problems, research in nuclear chemistry and chemical engineering developed vigorously.

An S&T staff was established which was complete in specializations, "both red and expert," and capable of fighting a hard battle.

After attacks on key problems with the atomic and hydrogen bombs, the focus of research in nuclear chemistry and chemical engineering shifted to nuclear fuel reprocessing technologies and technologies for processing waste water, waste gas, and industrial residues. After 1977, on the basis of completing applied research, work in nuclear chemistry and chemical engineering reinforced applied basic research and basic scientific research. Following is a brief introduction to the main aspects of work and accomplishments in nuclear chemistry and chemical engineering over the past 30-plus years in five areas (for a discussion of the relevant radioactive isotopes, stable-isotope separation, irradiation chemistry, and other topics related to nuclear chemistry and chemical engineering, see the related chapters of this book).

# 1. Tasks in solving key technical problems with the atomic and hydrogen bombs

From 1960 to 1966, the Institute of Atomic Energy and other units were responsible primarily for tasks in the following five areas:

(1) Developing neutron sources for the first atomic bomb. In 1960, the Uranium Chemistry Technology Group under group leader Wang Fangding [3769 2455 1353] in the Institute of Atomic Energy's Uranium and Plutonium Chemistry Research Office assumed responsibility for the task of developing neutron source raw materials. When they began their experiments, conditions were very poor, so the research personnel in the group took action themselves and worked with capital construction personnel for over 1 month to build a laboratory shed. When all of the needed equipment had been prepared, they moved into this simple radiation chemistry laboratory in the fall of 1960. In these simple and crude conditions, they worked together with the relevant research personnel in the Beijing Institute of Nuclear Weapons and after several hundred experiments, they developed a neutron source charge which conformed to the demands of nuclear weapons. Next, three people including elder worker Guo Kun [6753 0981] in the Precision Processing Group at the Experimental Plant of the Institute of Atomic Energy gave up their breaks and holidays to work night and day to produce very precise package casings. Three people, including Wang Shuren [3769 2885 0086], in the Metallic Physics Research Office attacked several technical problems with the packaging and solved problems with packaging the neutron sources. Five people including Zhu Jiaxuan [2612 1367 8830] in the Neutron Diffraction Group of the Neutron Physics Research Office used a neutron diffractometer after slight changes in the packaging and completed the final inspections for each group of neutron sources. Last, the Beijing Institute of Nuclear Weapons conducted experiments with neutron sources and confirmed that their performance met design requirements and that complete success had been attained.

(2) From 1960 to 1963, based on decisions of the Second Ministry of Machine-Building Industry, the Institute of Atomic Energy worked together with the Uranium Hexafluoride Production Plant and the Academy of Nuclear Engineering Research and Design for victorious completion of a project to produce a certain number of tons of uranium hexafluoride urgently needed at the Lanzhou

Uranium Enrichment Plant. Moreover, they examined and confirmed technical processes at the production plant and trained technical personnel; this played a role in guaranteeing the startup of the uranium-235 production line.

(3) To measure atomic bomb equivalents, the Institute of Atomic Energy, the Beijing Institute of Nuclear Weapons, and the National Defense Science Commission Test Base Area Institute cooperated to establish burnup analysis methods; they completed equivalent-measurement work after several nuclear tests.

The Institute of Atomic Energy also prepared special isotope tracer agents used for probes of nuclear test reaction effective energy; it achieved very good results during several nuclear tests.

(4) To make attacks on key technical problems with lithium-6 and lithium-deuterate production, Jin Xingnan [6855 2502 0589] and others completed theoretical computations concerning isotope separation. To meet the needs of nuclear tests, the Institute of Atomic Energy prepared high-purity uranium-235 and lithium-6, and cooperated with the CAS Chemistry Institute to use chemical exchange methods to prepare and provide boron-10 isotopes.

(5) Zhu Peiji [2612 1014 1015] and others in the Analysis Research Office of the Institute of Atomic Energy cooperated with the relevant units to establish analytical monitoring methods for the quality of uranium dioxide, uranium tetrafluoride, and uranium hexafluoride products.

## 2. Nuclear fuel cycle

(1) Preprocessing of uranium. In 1958, the Beijing Uranium Dressing Institute began to examine and confirm the technical processes for uranium dressing and smelting provided by the Soviet Union. After 1960, they undertook several projects for "attacks on key technical problems" and in the end successfully developed several technical processes of a particularly Chinese nature (see the chapter on ore smelting). The Oceanography Institute and several research units in coastal cities began work on the extraction of uranium from seawater and had some preliminary achievements.

(2) Uranium conversion. Technical preparations were made for the nuclear fuel plant to produce atomic bomb charges. The plant also developed a single-stage apron fluidized-bed to make uranium tetrafluoride from uranium dioxide and reduced unit HF consumption to 0.3 tons per ton of uranium tetrafluoride. The vertical countercurrent fluoridization furnace used to produce uranium hexafluoride and the use of one-step direct reduction denitrification of reactor-following uranyl nitrate to prepare uranium dioxide also were advanced methods developed only in China.

(3) Nuclear fuel reprocessing. Before 1963, the Institute of Atomic Energy, Beijing Nuclear Engineering Research and Design Academy, and other units digested, absorbed, and improved the technical procedures in the precipitation method supplied by the Soviet Union. At the same time, Qinghua University began "cold" experiment research on the internationally advanced

extraction procedure. In 1964, an expert survey group was organized especially for the purpose of surveys. The conclusion drawn by the group was that China could solve technical problems in the extraction method and that it was economically superior to the precipitation method. For this reason, the Institute of Atomic Energy, Qinghua University, Beijing Nuclear Engineering Research and Design Academy, the Reprocessing Plant at the Jiuquan Integrated Atomic Energy Enterprise, CAS Chemistry Institute, Changchun Applied Chemistry Institute, and other units cooperated for attacks on key technical problems. They used documents from foreign countries, and after 19 hot experiments they completed research on reprocessing extraction method technologies and used them in production. Afterwards, they also completed research experiments for the conversion from three cycles to two cycles in main reprocessing technologies, and they used them in production.

From 1977 to 1984, the Institute of Atomic Energy completed tandem experiments with reprocessing technology procedures for nuclear submarine power reactor fuels. In 1981, the Institute of Atomic Energy focused on reprocessing elements from nuclear power stations to conduct rather extensive research on a no-salt process of electrolytic oxidation reduction, hydroxylamine reduction, and other topics. Among them, electrolytic oxidation regulation of plutonium has been used in production. In addition, rather good achievements have been made in chemical engineering research on pulse extraction columns, irradiation degradation of solvents, improvements in oxalate precipitation, high-efficiency extraction of alpha nuclear elements from highly radioactive waste liquid, measurements of element burnup, and other areas. While working in the above areas, they studied various methods for separation and analysis of thorium, uranium, plutonium, neptunium, americium, curium, and fragmentation elements, as well as direct germanium lithium gamma energy spectra,  $\beta$ -gamma and gamma-alpha-coincidence low-background measurements, mass spectrum analysis, and other technologies.

(4) Development of new materials for chemical engineering. In the early 1960's, for the purpose of nuclear-fuel-cycle applications, the Ministry of Petroleum Industry, Ministry of Chemical Industry, Ministry of Metallurgical Industry, CAS, institutions of higher education, and other relevant units worked in close cooperation for research on the synthesis of new organic materials and special equipment for use in chemical engineering. Over the past 20-plus years, they did research on various types of ion-exchange resins, ion-exchange fibers, ion-exchange membranes, reverse-osmosis membranes, bonded-liquid-membrane leaching extraction, chelate resin, several types of extractants, flocculants, and several special reagents, special lubricating oils, fluoride-containing gaskets, spacers, valve fillers, and so on. The quality of some products has caught up to or surpassed that of similar products in foreign countries.

(5) Processing the "three wastes" [waste gas, waste liquid, and industrial residues] and comprehensive utilization. Over the past 30-plus years, research in dealing with the "three (radioactive) wastes" in China has developed gradually on the basis of the requirements of nuclear industry construction. It began with research on waste water and gas, and shifted later toward the solidification of weekly, moderately, and highly radioactive waste liquids, and terminal processing of wastes.

In 1964, the Institute of Atomic Energy began with a three-stage processing method for weakly radioactive waste liquid involving flocculation precipitation--evaporation--ion exchange for the purpose of conducting a large amount of scientific research work for technical improvements. Afterwards, they successfully conducted cold experiments in heat pump evaporation and a full ion-exchange fiber electrodialysis method. These two technologies are being widely used. Research at Beijing Normal University and the Institute of Atomic Energy on the use of an inorganic ion-exchange agent for separation of cesium-137 and strontium-90 in weakly radioactive waste liquid went rather well.

Levels were rather high in the synthesis of polyantimonic acid and titanium phosphate AMP at Beijing Normal University, in the use of fragmentation combustion processing for radioactive waste materials at the Irradiation Protection Institute, in the solidification of a plastic (polystyrene) for up to 65 percent containment of waste resins (by weight) at the Institute of Atomic Energy, and in research on the extraction of rhodium and palladium from reprocessed waste liquid at Beijing University. The Institute of Atomic Energy completed cold experiments on borosilicate canned-glass solidification of highly radioactive waste liquids from production reactors. On the basis of research on moderately radioactive bitumen solidification done at the Institute of Atomic Energy and the Beijing Academy of Nuclear Engineering Research and Design, the Reprocessing Plant completed a shop on an industrial scale. The Institute of Atomic Energy and Qinghua University also conducted research on moderately radioactive cement solidification. In 1982, the Jiuquan Integrated Atomic Energy Enterprise absorbed research achievements made at the Institute of Atomic Energy and Lanzhou University and established production shops for comprehensive extraction of cesium-137, strontium-90, tellurium-144, and promethium-147.

The Irradiation Protection Institute, Fourth Geology Brigade, and other units conducted research on terminal handling of radioactive waste materials. Examples include research on safety characteristics of terminal handling of cement solidified materials and highly radioactive solid glass blocks in shale strata, and experiments on underground migration of nuclear elements are now in progress.

### 3. Actinide chemistry

As the nuclear fuel industry was established and grew, many scientific research units and universities in China conducted research on the basic chemistry and analytical methods of actinides. Those carrying out the majority of the work include the Institute of Atomic Energy, Qinghua University, Beijing University, Fudan University, and Shanghai Organic Chemistry Institute, the Northwest Nuclear Technology Institute, Sichuan University, Tianjin University, Beijing Institute of Uranium Ore Dressing, and other units. Because they are restricted by conditions, however, only the Institute of Atomic Energy and a few other units have conducted work with neptunium, plutonium, and trans-plutonium elements.

In this realm, research projects which have the highest levels, the greatest significance, and particularly Chinese characteristics include: the structure of phosphorous and amine extractants and their relationship to uranium extraction behavior; study of various types of two-element and three-element co-extractant systems as uranium extractants; methods for computing non-electrolytic mass activity coefficients in uranium extraction systems; use of the potential method to control the degree of oxidation reduction of plutonium and neptunium in a nitrate solution system; and extraction method which extracts 99.9 percent of the americium, curium, uranium, and plutonium in highly-radioactive waste liquids; a method for separation and preparation of high-purity americium and curium; applications of new extractants (such as crown ether [guanmi--0385 5721]) in actinide separation and analysis; various oxidation reduction methods including electrochemistry and photochemistry; and so on.

#### 4. Nuclear chemistry

In the early 1970's, the Lanzhou Modern Physics Institute used heavy-ion reactions to synthesize californium-246, einsteinium-246, and fermium-250, and they used a cation-exchange method to separate and examine the californium obtained. They established a rapid separation determination device attached to their accelerator used to bombard zinc-64 with carbon-12 ions to create bromium-72, bromium-73, and bromium-74, which have half-lives on the order of a few minutes. Zhou Maolun [0719 2021 0243] at the Brookhaven National Laboratory in the United States cooperated with Zhu Yongyi [2612 3057 3015] and synthesized actinium-233 for the first time.

In the area of fission chemistry, the Lanzhou Modern Physics Institute used carbon-12 to bombard gold-197, bismuth-209, uranium-238, and other heavy nuclei. Using radiation chemistry methods for measurement of fission yields, the institute discovered that the width of the mass distribution increases rapidly as  $Z^2/A$  increases. While making precise measurements of fission product yields during 3-MeV and 8-MeV neutron-induced uranium-238 fission, they measured the yield of 85 nuclear elements, including 10 for which yields were reported for the first time.

#### 5. Analysis of nuclear fuels

After 1960, standard measurement methods were established for the various nuclear-fuel products. They included the activation-analysis method, emission spectra (including plasma emission spectra), spectrophotometry (including infrared and ultraviolet), NMR, atomic adsorption, laser fluorescence, electrochemistry (including polarogram and coulomb analysis), x-ray fluorescence analysis, x-ray scanning--microregion analysis, mass spectra (including spark source mass spectra), color spectra, isotope dilution methods, subchemical quantitative analysis methods, heat differential analysis, and so on. Notable among these was the laser-fluorescence method for uranium measurements with a detection limit of 0.01 ppb and a margin of error of  $\pm 10$  percent. When the measured uranium was 0.1 ppb, the margin of error was  $\pm 5$  percent. When the laser-fluorescence method was used to measure the samarium, europium, and dysprosium in rare-earth elements, the detection limit was up to 0.9 to



0.04 ppt. Beginning in 1973, under the guidance of chemical-analysis expert Chen Guozhen, the Beijing Academy of Nuclear Engineering Research and Design, Institute of Atomic Energy, Reprocessing Plant, and other units cooperated for successful research on automated analysis technologies. After being adopted in the Reprocessing Plant in 1979, data could be obtained as required in the production flow line, which has greatly reduced the radiation doses to which analytical personnel are exposed and provided very good production benefits.

#### Section 4. Research on nuclear reactor technologies

Research on reactor technologies in China began in the last half of 1956. At the time, the Physics Institute organized a 1-year reactor theory training class taught by Peng Huanwu and Huang Zuqia. Almost 20 people were enrolled as students. This produced China's first group of reactor theory research personnel. In 1958, the research heavy-water reactor built with Soviet assistance was turned over for production, after which China decided on tasks for self-research and design of a nuclear submarine power reactor, which motivated several experimental research projects on reactor technologies. Afterwards, for a period of almost 30 years, the main reactors studied, designed, and built in China included research reactors, reactors for nuclear-fuel production, pressurized-water power reactors, and so on. Ten reactors have been completed and placed into operation, an operating experience of 120 reactor-years has been accumulated, and a complete reactor technology scientific research system has been established. About 5,000 people are engaged in S&T work in this area, a work force that is capable of dealing with every topic and technical problem that appears during construction of research reactors, production reactors, and power reactors; it has the ability to digest new imported technologies and to explore and develop new types of reactors.

##### 1. Research on reactor physics

In 1958, the Institute of Atomic Energy established the Reactor Physics Experiment Group and gave it responsibility for physical startup of the research heavy-water reactor. In February 1959, under leadership by Zhu Guangya, the Institute of Atomic Energy worked by itself to design, manufacture, and install the first light-water zero-power facility; and it conducted some experiments in taking the first step toward understanding experimental technologies in research heavy-water reactor physics.

After 1961, the Reactor Theory Group of the Institute of Atomic Energy was combined with the Reactor Physics Experiment Group to form the Reactor Physics Research Office. It began theoretical computations for a materials testing reactor, an element testing reactor, and a production reactor. In addition, it also built several zero-power facilities and conducted some experimental confirmations of the computed results. Later, it cooperated with the Institute of Reactor Engineering and Technology, Shanghai Academy of Nuclear Engineering Research and Design, and other units to develop computing programs for Chinese-designed and manufactured submarine nuclear power reactors, high-flux experimental reactors, and the Qinshan Nuclear Power Plant reactor, and to conduct experimental confirmations at zero-power facilities.

After 1963, to provide a foundation for light-water reactor design, the Institute of Atomic Energy and the Southwest Academy of Reactor Engineering Research and Design conducted theoretical and experimental research on light-water reactor grids, performing precise theoretical analysis on experiments with uranium water grids. They conducted full-lifespan monitoring of the experimental reactor and they compared the theoretical computations with zero-power experiments. Between 1978 and 1983, the experimental heavy-water reactor completed in 1958 was rebuilt in conjunction with the Institute of Atomic Energy to conduct theoretical and experimental research on the physical characteristics of low-concentration uranium heavy water grids. They worked in conjunction with the Academy of Nuclear Engineering Research and Design to develop heavy-water nuclear power plants, and they conducted research on the physical characteristics of highly enriched uranium heavy water. They established a zirconium-hydride-pile zero-power facility for design and research on pulse reactors and studied neutron scattering in zirconium hydride. In addition, the Southwest Academy of Reactor Engineering Research and Design, Qinghua University, the Institute of Atomic Energy, and other units laid the developmental groundwork for reactor physics and wrote computation programs for nuclear heating and power plants and for high-temperature gas-cooled reactors. In the area of fast reactors, they conducted theoretical and experimental work on fast reactor control, Doppler effects, and criticality experiments.

Over the past 20-plus years, China has built nearly 20 zero-power facilities and over 10 of them were operating in 1984. The Southwest Academy of Reactor Engineering Research and Design has eight. The Chinese Academy of Atomic Energy Sciences has three. Qinghua University's Nuclear Energy Technology Institute has one, the Shanghai Atomic and Nuclear Institute has one, and so on.

## 2. Research on reactor thermohydraulics

In 1959, the Institute of Atomic Energy established China's first Reactor Thermohydraulics Laboratory, and it built more than 10 high-temperature, high-pressure water loops and other facilities for experiments on critical thermal flux densities, current-velocity distributions in element boxes, the resistance of certain components, and so on. All of these provided a foundation for solving certain key technical problems in design.

After 1965, various thermohydraulic experiment facilities were built at the Southwest Academy of Reactor Engineering Research and Design, Shanghai Atomic and Nuclear Institute, Qinghua University Nuclear Energy Technology Institute, Shanghai Jiaotong University, Xi'an Jiaotong University, and other units. Research personnel in these units jointly completed thermohydraulics experimental work on research reactors, reactors used in nuclear fuel production, and pressurized-water power reactors to provide the necessary data for reactor design, operation, and rebuilding.

In 1970, China built its first sodium heat transfer loop and conducted experiments on heat transfer coefficients of sodium circulating in pipes and casings. They gained experience in high-temperature sodium operations and took the first step in fast reactor heat transfer research in China. By 1984, the Chinese Academy of Atomic Energy Sciences, Shanghai Electric Appliance Sciences Institute, Baoji Plant No 902, and other units had built about 20 sodium loops and experimental facilities.

Through more than 20 years of practice, reactor steady-state thermohydraulic testing technologies attained rather high levels and rather accurate measurements were made of surface temperatures, single-phase pressure drops, local flow velocities, criticality determinations, two-phase cavitation portions, moderate and small flow rates, etc. In the area of theoretical analysis and computing programs for reactor thermohydraulics, there already are fairly complete steady-state analysis programs, while dynamic analysis computing programs and safety analysis and research have begun to take shape.

### 3. Research on nuclear reactor fuel elements

In 1958, research on reactor fuel elements was begun at the Institute of Atomic Energy and it was continued later after being shifted to the Baotou Fuel Elements Plant and other units. Over the past 20-plus year, design and processing of all types of fuel elements for research reactors, production reactors, and power reactors have been completed. The Institute of Atomic Energy established reactor interior and exterior examination loop facilities at the research heavy-water reactor and element testing reactor, and it conducted research on reactor interior and exterior testing of fuel elements for all types of reactors. During the late 1960's, a complete nuclear fuels and nuclear fuel elements research facility was completed at the Southwest Academy of Reactor Engineering Research and Design. A case in point is the high-flux experimental reactor completed in 1982; it has nine experimental ports and the corresponding irradiation technology and irradiation inspection measures which have created very favorable conditions for future reactor interior testing of nuclear power-plant fuel elements. Research also was conducted on damage detection in fuel elements, reactor-core measurement technologies, and sensors.

In 1983, the Institute of Atomic Energy established a high-temperature, high-pressure test loop at the research heavy water reactor after it had been rebuilt. Beginning in 1984, they examined and inspected fuel elements from the Qinshan Nuclear Power Plant.

### 4. Research on reactor materials

In the late 1950's, the Ministry of Metallurgical Industry, Ministry of Chemical Industry, relevant institutes in the CAS, the Reactor Materials Research Office in the Institute of Atomic Energy, and other units made major efforts at cooperation for experimental research; this was geared toward control analysis for the various relevant elements in materials used in reactors, mechanical properties of materials, welding properties, corrosion resistance properties, irradiation resistance properties, and other problems. After a long period of experimental research, they studied several types of

reactor materials. Since 1984, with the exception of a small amount of materials which need to be imported from foreign countries, performance indices of Chinese-made products for the other materials used in reactors have conformed to design requirements and are capable of meeting the demands of reactor construction. Work also is under way in China on tackling key problems in the development of the small amount of materials which must be imported at present, and grafting progress has been made.

#### 5. Analytical research on nuclear power-plant systems and the structural mechanics of equipment

The pressure vessel, main steam generators, main pumps, and pressure stabilizers of a reactor as well as their pipes, valves, and other equipment are high-pressure nuclear equipment. To assure the safety and reliability of this equipment, careful stress analysis and stress measurements were necessary during design.

In 1960, the CAS Harbin Capital Construction Institute (later renamed the Harbin Engineering Mechanics Institute) the Institute of Mechanics, the Academy of Nuclear Engineering Research and Design, and other units jointly organized forces for structural mechanics analysis and research for production reactor equipment. In 1963, the Reactor Engineering Technology Institute established the Reactor Structural Mechanics Research Office. In 1970, after this institute was combined with the Southwest Academy of Reactor Research and Design, they established a Static Experiment Console, Photoelastic Laboratory, Blast Destruction Laboratory, Foil Gage Development Laboratory, Shock Laboratory, Vibration Laboratory, Water Current Experiment Console, Subnormal Fatigue Experiment Console, and other equipment which created the conditions for good stress analysis of reactor equipment.

In addition, the CAS Mechanics Institute, the Harbin Mechanics Institute, the Seventh Academy of the Sixth Ministry of Machine-Building Industry, and other relevant units also conducted much research on reactor structural mechanics.

#### 6. Research on reactor hydrochemistry

Reactor hydrochemistry is a new scientific discipline which studies one- and two-loop water purification in reactors, thus extending the life of reactor structural materials and reducing levels of radioactivity in the loops.

In 1958, China began research on corrosion and protection of reactor materials. The Reactor Chemistry Research Office and the Reactor Materials Corrosion and Protection Research Office were established in reactor engineering research units under the Second Ministry of Machine-Building Industry, and they built several corrosion experiment consoles, steady-state high-temperature and high-pressure experimental cauldrons, and dynamic simulated corrosion experiment loops. Over the past 20-plus years, they studied several quick and accurate water quality analysis methods, and they observed water quality during daily reactor operation and provided timely data to assure safe reactor operation. A large amount of research carried

out on water purification and deoxidation technologies provided valuable conclusions and was used in engineering. To further intensify work on corrosion of reactor materials, research on corrosion electrochemistry in high-temperature and high-pressure pure water began in the early 1970's. In addition, excellent results were obtained in the area of preventing the corrosion of materials during research on highly effective, non-toxic, inexpensive, and irradiation tolerant corrosion-slowing agents, and on irradiation-tolerant coatings. Research on steam generator simulator dynamic corrosion now is undergoing long-term operational testing.

#### 7. Analysis of reactor safety

Analysis of reactor safety is the foundation of reactor engineering safety system design, and safety analysis must be conducted throughout the entire reactor research and design process.

In the late 1970's, reactor engineering research units in the Second Ministry of Machine-Building Industry began nuclear powerplant safety analysis for safety questions in light-water reactors, research on fuel elements under normal and emergency conditions, experimental research on water cutoff accidents, research on critical safety and reactor dynamics, environmental safety research for nuclear power plants, research on processing the waste gas and liquids, and industrial residues, and other areas. As the research work intensified, the corresponding experimental research facilities were constructed.

#### 8. Inspection of the reactor in commissioning

There are strict regulations for quality assurance in nuclear power plant design and construction. Nevertheless, the effects of various types of stress, corrosion, and other factors during operation of a nuclear power plant can cause faults (cracks), or latent defects may expand. For this reason, there must be strictly scheduled work inspection of the main reactor equipment and systems during the useful life of a nuclear power plant (generally 40 years) to permit early discovery of faults and quick measures to assure equipment and personal safety.

In the late 1970's, the Southwest Academy of Reactor Engineering Research and Design established the Reactor Work and Inspection Research Office, and it now has ultrasonic inspection equipment, steam generator heat transfer pipe multi-frequency eddy inspection systems, pressure vessel-top ultrasonic pantograph and television inspection systems, main pipeline ultrasonic inspection systems, pressure vessel main screw column single frequency eddy inspection facilities, irradiation-tolerant underwater television and image recording systems, irradiation-tolerant periscopes, fiber-optic lenses, and other equipment specifically for reactor pressure vessels. This laboratory has carried out inspections of the main components of China's power reactor with excellent results.

During the process of designing and building reactors in China, in addition to the above disciplines, quite a bit of work also was done in research on reactor control and measurement systems, instruments, equipment, and plant site selection. Examples include Chinese-designed and built reactor control systems used for operational practice testing of all types of reactors to assure safe reactor operation.

### Section 3. Nuclear devices for special uses [pp 453-460]

#### 1. Development and production of equipment for uranium-isotope separation

The presence or absence of highly enriched uranium production on an industrial scale is an important indicator of the level of a particular nation's nuclear industry. For this reason, the manufacture of equipment for isotope separation has become an important topic in the nuclear equipment manufacturing industry. China has gone through three main stages in this area: copying Soviet equipment, designing our own large-scale equipment, and studying and designing new equipment.

During the 1950's, gaseous diffusion was the main method used to produce highly enriched uranium on an industrial scale. The diffusers used in China's Lanzhou Uranium Enrichment Plant were imported from the Soviet Union. However, the special instruments, meters, and control equipment the Soviets provided were incomplete. The separation membranes and fluorine-tolerant lubricating oils which are the core diffuser components were consumable reserve and spare parts required for production, and they had to be based on China's own explorations and development. For this reason, the main task we faced during the 1970's and 1980's was to organize the development of diffusers, separation membranes, and other main components. The special central commission decided to assign responsibility for development of separation membranes to the CAS and the Second Ministry of Machine-Building Industry, and responsibility for development of fluorine-tolerant lubricating oils to the Petroleum Bureau in the Ministry of Chemical Industry.

The mechanical parts of the diffusers include compressors, electric motors, separation tubes, coolers, connecting pipes, and other components. Due to the large amount of work required to produce these components, the pattern of decentralized production of components and centralization of machine assembly was adopted to shorten production schedules. Thus, three production base areas were organized for final equipment assembly at the Beijing Heavy Electrical Equipment Plant, the Shanghai Electrical Equipment Plant, and the Harbin Gas Turbine Plant. The Ministry of Electronics Industry's Beijing Wired Telecommunication Plant was responsible for the needed control systems. Trial development and production of regulators and associated instruments and meters was the responsibility of the Xi'an Instrument Plant, the Nanjing Analytical Instruments Plant, and the Shanghai Guanghua Instruments Plant. The special bearings were trial developed and produced at the Wafangdian Bearing Plant and the Luoyang Bearing Plant. The vacuum valves of varying diameters were developed jointly by the Shanghai Valve Plant, the Shenyang High and Moderate Pressure Valve Plant, and the Suzhou Valve Plant.



The main technical qualities of diffusers are typical of nuclear equipment. The medium in the equipment is radioactive and extremely corrosive. All of the equipment is linked to form a large-volume vacuum system. While operating, the working medium cannot be allowed to leak and affect safety, nor can air be allowed to leak in and affect product quality. This means that the quality requirements for equipment manufacture are very high. Two main problems had to be dealt with when copying diffusers. One was the preparation of processing diagrams for manufacturing plants. The First Ministry of Machine-Building Industry and the Second Ministry of Machine-Building Industry spent about 1 year working jointly on the designs and completed them. The second problem was breakthroughs in key manufacturing technologies. These key technologies included cold pressing to form the volutes, and the difficult process of machining compressor blower wheels and guides and other complex components. Moreover, there were many new technical topics involved in welding, sealing, electroplating, polishing, and other areas. Through the combined efforts of the S&T personnel in the units responsible for the development tasks, these technical problems were solved one after another, and a prototype was completed in less than 2 years. During the process of trial manufacture, the newly built Tianjin Academy of Physical and Chemical Engineering Research and Design used the research and experiment base area to conduct a substantial amount of experimental examination and confirmation.

In September 1964, the 13-member Diffuser Examination and Acceptance Committee was established with Wang Xinmin [3769 2450 3046] as chairman, Wang Ziyi [3769 1311 0308] as vice chairman, and Ren Nai [0117 5082], Lu Rongguang [5684 2837 0342], Chen Zhengchen [7115 2973 3819], Wu Zipei [0702 2737 1014], and others as members. After several types of diffusers manufactured on a trial basis had been examined and accepted, they began batch production in the winter of 1964. Trial manufacturing and production tasks for the matching equipment had been completed, which satisfied the urgent needs in construction of the uranium enrichment plant. In November 1972, the First Ministry of Machine-Building Industry and the Second Ministry of Machine-Building Industry held a joint on-site meeting to examine and accept the quality of Chinese-made machinery. It was confirmed on the basis of operating results that, with the exception of a slightly high rate of equipment shutdowns during early periods, the Chinese-made diffusers were of excellent quality.

In 1964, based on decisions by the special central commission, the Ministry of Metallurgical Industry assumed responsibility for construction of the Separation Membrane Plant. This plant was completed in only 22 months and trial operation was successful on the first attempt in 1967, producing the first group of products meeting specifications. At the same time, they began work on developing new types of diffusers which passed state examination and acceptance in December 1979, providing important facilities for nuclear fuel production in China.

## 2. Manufacturing reactor equipment

Nuclear reactors are the main components of nuclear industry systems. China used Chinese-made equipment to prepare swimming-pool experimental reactors for use in scientific research, pulsed neutron reactors, and high-flux experimental reactors, and to rebuild heavy water experimental reactors. In the area of power reactors, China also manufactured nuclear submarine power reactors.

Breakthroughs in reactor equipment manufacturing technologies and manufacturing capabilities, however, came through reliance on our own efforts to build a graphite light-water production reactor during the 1960's.

China's first production reactor was a graphite light-water reactor with a simple technical piping structure. The pile was enormous in size and technically complex. There was a maze of pipes and the fuel loading and unloading equipment was clumsy and required a high degree of precision. Many components were pre-buried in the concrete, so most of the equipment was quite difficult to replace or repair. To guarantee its useful life, the quality requirements had to be extremely strict. Because of the cutoff of Soviet assistance, very little of the reactor equipment had been delivered and, with the exception of the support components for the reactor pile and the graphite, the main technical equipment basically had not been received, so the difficulties facing manufacture of reactor equipment at the time were even greater than those in the development of diffusers.

To make breakthroughs in the trial manufacture of production reactor equipment, the pattern of large-scale cooperation on key topics similar to that used during the manufacture of diffusers was adopted, although more units were involved and the scope was much broader. Enterprises like the Shanghai Gas Turbine Plant, Shanghai Boiler Plant, Wuhan Boiler Plant, Beijing No 1 Machine Tool Factory, Shenyang Water Pump Plant, and others were responsible for 154 types of equipment, including single loop cycling pumps, heat exchangers, cooling water collecting pipes, unloading structures, and so on. The auxiliary reactor systems and non-standard equipment were produced mainly by the Dalian Machine Manufacturing Plant. Among a total of 33 types of automatic control and monitoring instruments, enterprises under the Second Ministry of Machine-Building Industry were responsible for 24 types, including thermometers, cooling water flow meters for the technical piping, humidity alarms, and other things. The other nine types, which included membrane pressure differential meters and other things, were the responsibility of the Shnghai Guanghua Instrument Plant. The special aluminum materials and all of the technical piping were produced by the Ministry of Metallurgical Industry.

To varying degrees, all of these plants carried out technical transformations, rebuilt plant structures, established clean assembly rooms, filled in processing equipment and testing measures, and established many product performance testing consoles. In the area of technology, on the basis of research at the Wuhan Materials Protection Institute, the First Ministry of Machine-Building Industry and the Second Ministry of Machine-Building Industry

jointly published ten technical documents in 1964, including aluminum alloy anode-oxidation processing quality inspection conditions, equipment cleanliness technical conditions, welding line inspection regulations, and helium-gas-leak detection technical conditions. This was China's first group of technical regulation documents for the manufacture of nuclear equipment and they played an important role in guaranteeing the quality of reactor equipment. After 4 years of all-out efforts by all the employees in each of the manufacturing plants, all of the equipment was delivered to the work site, which guaranteed that the production reactor would be completed and go into operation on schedule.

Among the reactor equipment manufactured later, the large support components, graphite bricks, and other products were developed in China. The manufacturing technologies for the other equipment also were improved to varying degrees. For example, when taking into consideration the high river sand content, a horizontal bar was added to the impellers during manufacture of the intake water pumps and the structure of the sealing rinks was improved, which increased pump life. The dual-roller support is the support for the screen structure below the pile. After experimentation, the thickness of the lower central plate was increased and the radius of curvature was expanded, which increase the load bearing capacity by 70 percent. The pipe diameters of the main heat exchangers were increased, which increased the heat exchange area and heat transfer efficiency. The small new grouped flow meters successfully developed in China replaced the copied products and they improved monitoring and control systems. Thus, all of the equipment manufactured for the production reactor was made in China.

The power reactors used in China's nuclear submarines are pressurized-water reactors. They are characterized by small size, high pressure and temperature parameters, compact equipment configurations, and other qualities. The comparison with production reactors is obvious, and this brings new problems for equipment manufacture. To accelerate equipment development, an experts' conference of more than 300 people from 70 plants, academies, and institutes was convened, and they split into groups to study and solve key technical problems in equipment and instrument development. Heilongjiang and the Wuhan region also convened their own expert conferences to assist plants responsible for equipment manufacture in achieving good cooperation and timely completion of the development and production of the primary components. In May 1970, installation and debugging of model reactor equipment got underway and reactor startup was successful on the first try. This accomplishment accumulated practical experience in research, design, and manufacture of nuclear power reactors in China.

The high-flux experimental reactor completed in the late 1970's was achieved through large-scale cooperation by more than 200 industrial and mining enterprises in China. Of the 6,508 pieces of 515 types of equipment, plants under the First Ministry of Machine-Building Industry completed 3,104 pieces of 165 types. Third-line newly built nuclear equipment manufacturing enterprises shouldered a heavy burden. The pressure vessels, heat exchangers, single-loop cycling pumps, safety valves, and other items were manufactured by the Deyang No 2 Heavy Machinery Plant, Dongfanghong Boiler Plant, Chongqing

Water Pump Plant, and Zigong High-Pressure Valve Plant. At the time, equipment manufacturing plants in the Second Ministry of Machine-Building Industry had already begun to grow. The Xi'an Machinery and Equipment Manufacturing Plant, the Xi'an Nuclear Instruments Plant, and others participated in building this project. The completion and startup of the high-flux experimental reactor showed that China's nuclear equipment manufacturing capacity was no longer limited to backbone enterprises in first-line coastal cities and that the new third-line plants had become a component part of China's nuclear equipment manufacturing industry.

After being included in state plans in 1982, most of the needed equipment for the Qinshan Nuclear Power Plant, which was designed and built by China, was manufactured in China. Because the state expenditures had not yet been transformed into production forces and breakthroughs had not yet been made in some technologies, we still were forced to rely temporarily on imports of some heavy and complex electrical equipment.

### 3. Manufacturing reprocessing plant equipment

A reprocessing plant is characterized by intense radioactivity, strong corrosion, and the risk of supercritical accidents. This demands that sealed equipment be used for all operations and that they be carried out remotely outside a very thick screen. In addition, operations must be monitored by instruments tolerant to irradiation and able to transmit signals over long distances.

Successful testing of the extraction method process in 1964 in China was followed almost immediately by construction of the pilot plant. To fight for time, the method of triple integration of design, manufacturing, and user departments was adopted. Design personnel in the Beijing Academy of Nuclear Engineering Research and Design worked together with engineering and technical personnel and workers in the Dalian Machine Manufacturing Plant to study processing methods and prepare a design based on the equipment and technical capabilities of the manufacturing plant. The plant and the academy cooperated closely without delays and accelerated the pace of equipment manufacture. In less than 2 years, they produced 370 types of equipment, including large hot rooms, sampling cabinets, compound clarification tanks, mechanical hands, wall-penetrating valves, and so on. The Shanghai Guanghua Instrument Plant adopted the pattern of triple integration to work under crude and simple conditions to develop and produce several dozen varieties of liquid level, density, flow rate, concentration, and other types of meters. The pilot plant went into formal operation in 1968. On the basis of this success, the large reprocessing plant which contained more than 500 types of special-purpose equipment and instruments was completed in 1970. Prior to this, the Plutonium Smelting and Casting Plant, which the Soviet Union had refused to supply with any equipment, and the Dalian Machinery Manufacturing Plant developed more than 90 percent of the equipment and used simple methods to move forward, completing the plant in 1963.

In this way, China's reprocessing plants were outfitted entirely with Chinese-made equipment. Chief Engineer Jiang Kunxiang [5592 0981 4382] at the Dalian Machinery Manufacturing Plant made substantial contributions to manufacturing equipment for the Reprocessing Plant and other special-purpose equipment.

#### 4. Providing equipment for research on nuclear fission

China began work to develop nuclear fusion equipment in the 1970's. In 1973, the Southwest Physics Institute worked with the Shanghai Xianfeng Electrical Equipment Plant to develop a steady-state strong-current ion injector. This was a high-temperature-plasma steady-state superconducting magnet facility with deflection magnets weighing more than 30 tons. This facility concentrated ultra-high vacuum, ultra-low temperature, and superconducting materials technologies in one entity and pushed research on plasma and fusion in China a step forward.

Next, with state approval, the task of building a Chinese Tokamak nuclear fusion experimental facility--the China HL1--was proposed. This facility is composed of three main parts: the power source (including high-power AC pulse generators, high-power pulse-rectification equipment, and pulse transformers), the ultra-high vacuum generator, and the main machine, and it also has the necessary plasma diagnosis and testing equipment. The AC pulse generators were jointly designed by the Southwest Physics Institute, Zhejiang University, Central China College of Engineering, and the Shanghai Electrical Equipment Plant, and manufactured by the Shanghai Electrical Equipment Plant. They were completed in 1979. The high-power pulse silicon rectification equipment was designed and manufactured by the Central China College of Engineering. The pulse transformers were manufactured by the Shenyang Transformer Plant. The ultra-high-vacuum system composed of titanium steam generators, diffusion pump air suction generators, eddy pumps, titanium pumps, and molecular sieve air suction generators were successfully developed by the Shenyang Vacuum Technology Institute.

The Dalian Machinery Manufacturing Plant was responsible for manufacturing the main equipment in the HL1, a process which was very difficult and repetitious. Under the organizational leadership of Chief Engineer Xu Jizhong [1776 4949 1813], the plant worked closely with the Southwest Physics Institute and developed more than 30 major key technologies involving pressure shaping and processing of the half-rings for the exterior vacuum chambers, welding the thin plate and forming the corrugated pipes for the internal vacuum chamber, metallic and ceramic bonding for the protection ring, intermediate-frequency bore welding of connectors to the wires of the vertical field coils, and so on, and they were manufactured successfully in 1982. The Southwest Physics Institute cooperated closely with the Suzhou Optical Instruments Plant for successful development of China's first Mach-Zehnder interferometer. Next, they developed high-speed spectral scanners used to measure the density and temperature of plasmas. Afterwards, they developed rotating drum scanning cameras used to photograph images of plasma changes and provided the matching plasma diagnosis equipment for the HL1.

After more than 2 years spent on installation and debugging, the China HL1 was finally completed in 1984, and it passed state examination and acceptance in November 1985. A comparison with Tokamak facilities in other countries, although China's equipment is only at an intermediate level in terms of scale, does show that China has made breakthroughs in equipment manufacture and experimental research on controlled thermonuclear fusion.

History over the past 30 years has shown that by starting with the technical characteristics of nuclear instrument and equipment manufacture and the development needs of the nuclear industry, the establishment of several special plants to manufacture nuclear instruments and equipment is necessary. These plants are closely linked with the scientific research, design, and production units in the nuclear industry, and they can organize experiments and production at any time based on the development needs of the nuclear industry and nuclear S&T. They also are better adapted to the characteristics of nuclear instruments and equipment, which are: they come in many varieties, are produced in small numbers, have urgent time requirements, rather complex technologies, and rapid replacement schedules. Supporting this sort of highly adaptable and flexible technical force will have positive effects on accumulation of manufacturing technologies and experiences to sustain and develop nuclear instruments and equipment.



## REFERENCES

### 1. Units participating in nuclear data work:

Chinese Academy of Atomic Energy Sciences  
Sichuan University Institute of Nuclear Science and Technology  
Beijing University Physics Department and Technical Physics Department  
Fudan University Second Physics Department  
Jilin University Physics Department  
Lanzhou University Modern Physics Department  
Shanghai Institute of Atomic and Nuclear Research  
Nanjing University Physics Department  
Qinghua University Engineering Physics Department and Nuclear Energy Institute  
Beijing Normal University Low-Energy Nuclear Physics Institute  
Nankai University Physics Department  
Nankai University Mathematics Department  
Zhongshan University Physics Department  
Guangxi University Physics Department  
Zhengzhou University Physics Department  
Wuhan University Physics Department  
Northwest University Physics Department  
Guizhou University Physics Department  
Hengyang College of Engineering  
Southwest Academy of Reactor Engineering Research and Design  
Beijing Academy of Nuclear Engineering Research and Design  
Shanghai Academy of Nuclear Engineering Research and Design  
Southwest Physics and Chemistry Institute  
Beijing Applied Physics and Computing Mathematics Institute  
Southwest Physics Institute  
Ministry of Nuclear Industry S&T Information Office

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Appendix: Chronology of Events in Chinese Nuclear Industry (May 1950 to December 1984)

1950

19 May: The Modern Physics Institute of the Chinese Academy of Sciences [CAS] was founded, and the State Council appointed Wu Youxun [0702 2589 6064] as director and Qian Sanqiang [6929 0005 1730] as deputy director.

17 October: The Modern Physics Institute decided to do research in theoretical physics, atomic and nuclear physics, cosmic rays, radiation chemistry, and other fields, with a focus on research in atomic and nuclear physics.

1951

13 February: Qian Sanqiang became director of the Modern Physics Institute.

1952

8 October: The Modern Physics Institute formulated the First 5-Year Plan for the Development of Nuclear Science and Technology from 1953 to 1957. Its goal was to use research on nuclear science and technology to create the conditions for greater development of nuclear physics experiments and reactor construction.

1953

6 October: The CAS Modern Physics Institute changed its name to the CAS Physical Institute.

1954

Minister Li Siguang [2621 0934 0342] of the Ministry of Geology and State Council Third Office Deputy Director and Ministry of Geology Vice Minister Liu Jie [0491 2638] reported on the China's uranium ore situation to Mao Zedong, Zhou Enlai, and other central authorities. Mao Zedong said that China should develop atomic energy.

December: (1) The Second Office of the Ministry of Geology Survey Commission was founded and given the primary task of developing preparations for the uranium geology industry in China; (2) Zhou Enlai instructed the CAS to organize the relevant scientists and educators in Beijing to explain scientific knowledge on atomic energy to central authorities, ministry CPC commissions, and local leaders; (3) The Yunnan Luoxue Shan High Mountain Cosmic Ray Laboratory was completed.

1955

15 January: Mao Zedong chaired an expanded meeting of the CPC Secretariat to discuss and decide on construction of the atomic energy industry, and Mao Zedong gave an important speech on this subject. Li Siguang, Liu Jie, and Qian Sanqiang attended the meeting as non-voting members.

20 January: China and the Soviet Union signed an agreement on joint Sino-Soviet exploration for uranium ore in China.

31 January: The State Council held its 4th Full Session and approved the decision on the question of accepting Soviet assistance to China in atomic energy research and utilization.

31 March: Mao Zedong pointed out at the National CPC Congress that: "We have entered a new historical era of digging into socialist industrialization, digging into socialist transformation, digging into modernized national defense, and even beginning to dig into atomic energy."

27 April: China and the Soviet Union signed the "Agreement on USSR Assistance to the PRC in Developing Research on Atomic Energy and Nuclear Physics and on the Need To Utilize Atomic Energy in the National Economy."

April: The Third Bureau of the Ministry of Geology was established with Lei Rongtian [7191 2837 1131] as bureau director. The State Council Third Office provided leadership and primary administration of geological exploration for uranium ore. The former Second Office of the Ministry of Geology Survey Commission was abolished.

1 July: The Construction Technology Bureau of the National Construction Commission was established with Liu Wei [0491 0251] as bureau director to administer Soviet aid to build a research heavy water reactor and cyclotron.

4 July: The CPC Central Committee instructed Chen Yun [7115 0061], Nie Rongzhen [5119 2837 5271], and Bo Yibo [5631 0001 3134] to form a three-person leadership group to be responsible for guiding development of the atomic energy industry.

19 October: Qian Sanqiang, Peng Huanwu [1756 2719 2976], and others in a group of 13 visited the Soviet Union to participate in examining the "one reactor, one device" design, consult with the Soviet Union on the allocation of Chinese study personnel among specializations, and other matters.

4 November: China sent 26 S&T personnel (including 13 graduate students and visiting students studying in the Soviet Union) to the Soviet Union to study reactor and accelerator technologies, theoretical physics, and experimental physics.

10 December: The State Council's Third Office formulated the "Outline Plan for the Development of the Atomic Energy Industry from 1956 to 1967 (Draft)". The principle put forth in the "Outline" was: "with substantial assistance from the Soviet Union, to build China's own atomic energy industry and have China use the most modern science and technology to develop the national economy and consolidate national defense."

1956

14 January: Zhou Enlai pointed out in his "Report on the Question of Intellectuals" that "the peak in new developments in science and technology is the utilization of atomic energy. Atomic energy provides mankind with an incomparably powerful new power source, and it opens up broad prospects for all scientific disciplines."

20 March: Eleven nations including the Soviet Union held an international conference in Moscow on the question of establishing a joint atomic and nuclear research institute.

26 March: Lie Jie signed the 11-nation "Decision on Establishing a Joint Atomic and Nuclear Research Institute" on behalf of the PRC.

April: The peaceful use of atomic energy was included among 12 key tasks in the 12-Year Long-Term Plan (1956 to 1967) for the Development of S&T in China.

23 April: The CPC Central Committee issued its "Notice on Transferring Cadres and Workers To Participate in Atomic Energy Construction," and transferred cadres and workers from 15 provinces, municipalities, and autonomous regions, and from 37 departments of the central authorities to participate in building the atomic energy industry.

25 April: Mao Zedong pointed out in an expanded meeting of the CPC Central Committee Politburo that China needed the atomic bomb: "in today's world, if we do not wish to be bullied by everyone, we must have this thing."

25 May: Construction of the research heavy water reactor and the cyclotron began at Tuoli in Fangshan County, Beijing Municipality.

15 September: The 8th National CPC Congress approved two reports by Liu Shaoqi and Zhou Enlai and the "Second 5-Year Plan," both of which emphasized the need for active development of the atomic energy industry.

September: The CAS Physics Institute established the Lanzhou Physics Research Office.

16 November: The 51st Session of the Standing Committee of the First National People's Congress approved the decision to establish the "Third Ministry of Machine-Building Industry of the PRC" to manage construction and development of China's nuclear industry. Song Renqiong [1345 0117 4522] was minister, Liu Jie, Yuan Chenglong [5913 2052 7127], Liu Wei, Lei Rongtian, and Qian Sanqiang were vice ministers, and Zhang Xianjin [1728 3759 6855] and He Kexi [0149 0344 1585] were assistant ministers.

19 December: China and the Soviet Union signed a new agreement on Soviet aid in uranium ore prospecting in China. This rescinded the old agreement of 20 January 1955 and joint Sino-Soviet management was changed to management by China herself.

1957

11 March: The Third Ministry of Machine-Building Industry formulated a plan program for construction of the atomic energy industry during the Second 5-Year Plan, and it was approved by Zhou Enlai and the CPC Central Committee.

15 October: China and the Soviet Union signed a new agreement on national defense technologies.

1958

17 January: The CPC Central Committee approved the report of the Third Ministry of Machine-Building Industry concerning the transfer of 215 cadres to seven units, including three plants in northwest China, the Engineering Design Academy, and others.

22 January: The Ministry of Metallurgical Industry established its Third Company to be responsible for building uranium mines, water dressing plants, and the Baotou Fuel Element Plant in Nei Monggol.

11 February: The 5th Session of the First National People's Congress decided to change the name of the Third Ministry of Machine-Building Industry to the Second Ministry of Machine-Building Industry.

March: With approval by the CPC Central Committee, the Second Ministry of Machine-Building Industry picked 5,000 employees in the Ministry of Construction Engineering's Lanzhou Construction Engineering Bureau to organize the No 101, No 102, and No 103 Construction Engineering Companies to be responsible for civil engineering construction of the three projects, respectively, the Ministry of Machine-Building Industry's Lanzhou Uranium Enrichment Plant, the Jiuquan Integrated Atomic Energy Enterprise, and the Northwest Nuclear Weapons Development Base Area in Qinghai.

16 May: Mao Zedong pointed out in a report to the Second Ministry of Machine-Building Industry that "we should respect our Soviet comrades and work hard to study from them. But, we certainly must eliminate superstition and smash Jiagui! No one should respect Jiagui (a lackey)."

31 May: CPC Central Committee General Secretary Deng Xiaoping approved site selection programs for five plants (the Hengyang Water Dressing Plant, Baotou Nuclear Fuel Element Plant, Lanzhou Uranium Enrichment Plant, Jiuquan Integrated Atomic Energy Enterprise, and Northwest Nuclear Weapons Development Base Area) and three mines (the Chenxian Uranium Mine, Hengshan Dapu Uranium Mine, and Shangrao Uranium Mine) in a report submitted by the Second Ministry of Machine-Building Industry.

21 June: Mao Zedong pointed out in a speech at an expanded meeting of the CPC Central Committee Military Commission that "I consider it entirely possible for China to develop atomic bombs, hydrogen bombs, and intercontinental missiles within 10 years."

1 July: RENMIN RIBAO reported the completion of the research heavy water reactor and cyclotron. The CAS Physics Institute was renamed the CAS Institute of Atomic Energy.

8 July: The CPC Central Committee approved and passed on the "Report on National Development of Uranium Mines" submitted on 30 June by the Second Ministry of Machine-Building Industry.

August: With approval by the CPC Central Committee, the Second Ministry of Machine-Building Industry transferred 700 people from the Ministry of Construction Engineering's Lanzhou No 9 Equipment Installation Company and 500 people from the First Ministry of Machine-Building Industry, the Ministry of Metallurgical Industry, the Ministry of Chemical Industry, and other units to organize the Second Ministry of Machine-Building Industry's No 103 Installation Engineering Company to take responsibility for equipment installation tasks for the three projects at the Lanzhou Uranium Enrichment Plant, the Jiuquan Integrated Atomic Energy Enterprise, and the Qinghai Northwest Nuclear Weapons Development Base Area.

24 August: The Second Ministry of Machine-Building Industry submitted its "Opinions on Principles and Plans for Development of the Atomic Energy Industry" to the CPC Central Committee and proposed the concrete work principles of "arduous struggle for 3 years to gain a fundamental grasp of atomic energy S&T" and "combining work with study, completion and mastery."

August: The CPC Central Committee issued the document "On New Technical Questions in Development of Naval Submarines" and decided to make the Second Ministry of Machine-Building Industry responsible for research and design tasks related to nuclear submarine power reactors, control systems, protective equipment, and so on.

11 September: The CPC Central Committee issued notice that more than 16,000 cadres and workers from various related departments would be transferred to supplement construction staffs in the nuclear industry.

13 September: The Ministry of Construction Engineering Beijing Third Industrial Structure Design Academy was placed under the Second Ministry of Machine-Building Industry and renamed the Second Ministry of Machine-Building Industry Design Academy.

27 September: The research heavy water reactor and cyclotron built with Soviet assistance were formally handed over for production. The State Council held an on-site transfer to production ceremony. RENMIN RIBAO published the editorial "Everyone Should Become Involved in Atomic Energy Science."

1 October: China's first research reactor produced 33 isotopes.

15 October: The CPC Central Committee approved and passed on the Second Ministry of Machine-Building Industry and CAS requests for instruction "On the Question of Everyone Becoming Involved in Atomic Energy" and "On the Question of Application and Extension of Radioactive Isotopes."



December: The Ministry of Metallurgical Industry Third Company was placed under the Second Ministry of Machine-Building Industry and renamed the Second Ministry of Machine-Building Industry No 12 Bureau (Uranium Ore Smelting Bureau).

1959

20 January: Wang Ganchang [3769 3227 2490] was chosen as deputy director of the Dubna Joint Institute of Atomic and Nuclear Research.

20 February to 1 March: The Second Ministry of Machine-Building Industry held a "Leap Forward Presentation Activists Congress" in Beijing. Zhou Enlai, Zhu De, and others met with the delegates.

24 February: The first Chinese-designed zero-power facility was completed.

20 June: The Central Committee of the Soviet Communist Party sent a letter to the CPC Central Committee refusing to provide mathematical models and technical data for the atomic bomb.

July: Zhou Enlai transmitted to Song Renqiong the decision of central authorities to "start working ourselves, probe our way from the start, prepare to spend 8 years to develop the atomic bomb."

23 December: The Second Ministry of Machine-Building Industry formulated an 8-year outline plan for the atomic energy industry which set forth the goal of "breakthroughs for 3 years, 5 years to gain an understanding, 8 years to make suitable preparations."

1960

January: The CPC Central Committee approved the transfer by the Second Ministry of Machine-Building Industry of 106 advanced and intermediate-level S&T key personnel from throughout China to reinforce nuclear weapons development work.

January: Mao Zedong, speaking on the question of whether or not technical renewal of the technologies and primary technical equipment imported from the Soviet Union was necessary, told Song Renqiong that like a small child writing, we first must write block characters, and then script.

19 January: The Institute of Atomic Energy began construction of a swimming pool-type research reactor project.

12 February: The Uranium Enrichment Laboratory of the Institute of Atomic Energy was completed and formally turned over for production.

March: The research group led by Wang Ganchang at the Integrated Institute of Atomic and Nuclear Research discovered sigma minus hyperons.

April: The Second Ministry of Machine-Building Industry decided that first-term projects in nuclear industry construction should focus on the uranium-235 production line, and that the Uranium Enrichment Plant should be the focus within the focus.

10 June: The Ministry of Commerce and the General Logistics Department of the PLA decided to build a comprehensive two-stage wholesale station at Lanzhou to reinforce supplies of materials for the special military units and departments in northwestern areas. All enterprise units under the Second Ministry of Machine-Building Industry in this area were included within the range of supply.

16 July: The government of the Soviet Union unilaterally tore up all agreements and contracts it had signed with China.

18 July: Mao Zedong pointed out in a meeting at Beidaihe that: we must make a firm decision to work on incisive technologies. If Krushchev does not give us incisive technologies, that's great! If they were provided, it would be hard to repay the debt.

9 August: The Second Ministry of Machine-Building Industry telegraphed its instruction "struggle for the principle of total reliance on our own efforts in China's atomic energy industry" to the units under its jurisdiction.

23 August: All Soviet experts working in the Second Ministry of Machine Building Industry left.

10 September: The CPC Central Committee appointed Liu Jie as secretary of the leading CPC group in the Second Ministry of Machine-Building Industry and Liu Wei as CPC group deputy secretary.

30 September: Liu Jie was appointed Minister of the Second Ministry of Machine-Building Industry.

1 October: The Second Ministry of Machine-Building Industry established the Nuclear Safety and Public Health Protection Bureau and placed the Industrial Public Health Bureau of the Ministry of Public Health under dual leadership by the two ministries to manage public health protection work in the nuclear industry.

December: Trial production with the facility was successful using a simplified method for uranium hexafluoride production and products meeting specifications were obtained.

December: The Second Ministry of Machine-Building Industry affirmed the work principle of "relying on our own efforts, making attacks on key technical problems, quality first, safety first."

1961

28 March: Portions of the Radiation Biology Office and the Technical Safety Office in the Institute of Atomic Energy were moved to Taiyuan and combined with the Taiyuan North China Institute of Atomic Energy to establish the North China Industrial Public Health Institute.

8 May: In its "Request for Instructions on Certain Questions" to central authorities, the Second Ministry of Machine-Building Industry made a detailed report of progress as well as problems and questions in nuclear industry construction and offered some suggestions.

16 July: The CPC Central Committee issued its "Decision on Reinforcing Certain Issues in Atomic Energy Industry Construction" which put forth the opinion of central authorities that the best way to rely on our own efforts to make breakthroughs in atomic energy technologies and accelerate construction of the atomic energy industry in China would be to shorten battlelines, concentrate forces, and strengthen support in areas related to atomic energy industry construction.

24 July: The CPC Central Committee decided to transfer key technical cadres, advanced medical cadres, and administrative cadres from all parts of China to participate in nuclear industry construction.

October: The State Planning Commission and the First Ministry of Machine-Building Industry decided to place the Tianjin Drill Boring Lathe Plant, the Beijing Comprehensive Instrument Plant, the Shanghai Guanghua Instrument Plant, and the Suzhou Valve Plant under the jurisdiction of the Second Ministry of Machine-Building Industry.

29 November: The CPC Central Committee decided to establish the National Defense Industry Office in the State Council to manage work in areas under jurisdiction of the Second Ministry of Machine-Building Industry, the Third Ministry of Machine-Building Industry, and the National Defense Science Commission. Luo Ruiqing [5012 3843 0615] was made director of the National Defense Industry Office and Zhao Erlu [6392 1422 7120], Sun Zhiyuan [1327 1807 6678], Fang Qiang [2455 1730], Liu Jie and Liu Xiyao [0491 6007 1031] were appointed deputy directors.

December: The First and Second Ministries of Machine-Building Industry jointly proposed the "7-Year Plan To Reinforce Atomic Energy Industry Equipment Development."

1962

April: Trial extraction at the Linxian Uranium Mine in Hunan Province began.

August: The State Council appointed Liu Qisheng [0491 3217 3932] as vice minister of the Second Ministry of Machine Building Industry.

11 September: Under the direction of Vice Premier Luo Ruiqing, the Second Ministry of Machine Building Industry wrote its "Report on Relying on Our Own Efforts To Build an Atomic Energy Industry" to the CPC Central Committee and Mao Zedong. The report set forth the strategic goal of trying to conduct the first atomic bomb blast test in 1964 or the first half of 1965. On 3 November, Mao Zedong gave the instruction: "Very good, act accordingly. We must strive to cooperate and complete this work."

3 November: The Shangrao Uranium Mine in Jiangxi Province passed state inspection and began formal operation.

17 November: To reinforce leadership over the nuclear industry, the CPC Central Committee decided to establish a 15-person special commission of central authorities with Zhou Enlai as director and with seven vice premiers in the State Council and seven minister-level cadres as members. A management organ was established in the National Defense Industry Office.

22 November: The Second Ministry of Machine-Building Industry formulated its "Outline Plan for 1963 and 1964 in Atomic Weapons and Industrial Construction and Production."

4 December: The 3d meeting of the special central commission discussed and approved the 2-year work plan for 1963 and 1964 proposed by the Second Ministry of Machine-Building Industry.

December: The Uranium Tetrafluoride Shop at the Baotou Fuel Element Plant was loaded and went into production.

December: The Isotope Applications Research Office of the Institute of Atomic Energy was moved to Shanghai and combined with the Shanghai Atomic and Nuclear Institute.

1963

21 January: The National Defense Industry Office and the National Defense Science Commission assigned a joint work group to inspect work in the Second Ministry of Machine-Building Industry.

19 to 21 March: The 4th and 5th meetings of the special central commission discussed and approved the overall pace and measures planned for the primary work tasks over a 2-year period in the Second Ministry of Machine-Building Industry. During his speech at the meeting, Zhou Enlai called on leaders in the Second Ministry of Machine-Building Industry from top to bottom to have high degrees of political ideology, scientific planning, and organizational discipline.

2 April: Mao Zedong, Zhou Enlai, Peng Zhen, Chen Yi, Tan Zhenlin [6223 7201 2651], Li Fuchun [2621 1381 2504], Bo Yibo, and other national leaders met with delegates to the Conference on the Laws of Uranium Ore Mineralization in the Second Ministry of Machine-Building Industry.

2 April: The CPC Central Committee formally issued a document agreeing to the establishment of a Political Department in the Second Ministry of Machine-Building Industry and a change of the party group in the Second Ministry of Machine-Building Industry to a party committee.

19 May: The special central commission issued its "Decision on Manufacturing Atomic Energy Equipment and Instruments."

5 July: Niu Shushen [3662 2579 3947] received concurrent appointments as vice minister of the Second Ministry of Machine-Building Industry and director of the Political Department.

24 July: Liu Xiyao was appointed vice minister and CPC group deputy secretary in the Second Ministry of Machine-Building Industry.

26 July: After listening to the report of the Integrated Inspection Group on work in the Second Ministry of Machine-Building Industry, the 6th meeting of the special central commission concluded that work in the Second Ministry of Machine-Building Industry basically was good. In the future, they had to guard against arrogance and rashness, be very careful, prevent any type of carelessness in work, avoid all preventable accidents, and strive to achieve the 2-year plan.

23 August: The first period project at the Hengyang Uranium Water Dressing Plant was completed and went into trial production.

29 November: The Uranium Hexafluoride Plant produced the first group of products meeting specifications.

4 December: Qian Xinzong [6929 0207 1813] was appointed vice minister of the Second Ministry of Machine-Building Industry.

24 December: The 1:2 nuclear charge fusion blast-generated neutron experiment was successful.

1964

January: The Second Ministry of Machine-Building Industry decided to establish the Reactor Engineering Institute to assume responsibility for research on nuclear submarine power reactors and other types of reactors.

14 January: The Lanzhou Uranium Enrichment Plant obtain highly-enriched product meeting specifications.

31 January: The special central commission proposed in a report to the CPC Central Committee and Mao Zedong that, for national defense and the principle of "location in mountainous areas, decentralization, concealment," a readjustment in the strategic deployment of the nuclear industry should be carried out as quickly as possible to build rear-line base areas.

April: The Second Ministry of Machine-Building Industry began organizing research work on large scale diffusers.

1 May: The first set of uranium-235 components meeting specifications was produced.

20 May: The Second Ministry of Machine-Building Industry decided to stop using the precipitation method used in the original design for the chemical industry reprocessing plant and shift to an extraction method process.

6 June: The Northwest Nuclear Weapons Development Base Area conducted the first 1:1 model blast experiment and the predicted goals were attained.

14 July: Zhou Enlai issued important instructions on questions for attention during rehearsals for the first nuclear test.

25 August: The Baotou Nuclear Fuel Element Plant produced uranium cores for elements which met specifications.

16 to 17 September: The special central commission convened its 9th meeting to discuss preparations for China's first nuclear test, short-term developments in the atomic energy industry, and readjustments in the strategic deployment of industry.

17 September: The Baotou Fuel Elements Plant produced lithium-6 products meeting specifications.

4 October: With CPC Central Committee approval, Liu Jie became secretary of the Second Ministry of Machine-Building Industry CPC Committee. Liu Xiyao and Liu Wei became deputy secretaries.

7 October: The Second Ministry of Machine-Building Industry issued its "Outline Activities for Readjustments in Strategic Deployments and Surprise Attacks on Construction of a New Third-Line Base Area."

1500 Hours 16 October: China successfully carried out its first nuclear test. Xinhua Agency reported the news. The Chinese government declared solemnly that China would not at any time or under any circumstances be the first to use nuclear weapons.

17 October: Zhou Enlai telephoned several world leaders to transmit the opinions of the Chinese government concerning the convening of a conference of all the world's heads of states to discuss the complete prohibition and total elimination of nuclear weapons.

1 December: The Second Ministry of Machine-Building Industry issued its "Work Outline To Accelerate Construction of a Plutonium Production Line."



3 December: In its "Report on the Question of Accelerating the Development of Nuclear Weapons" to the CPC Central Committee, the Second Ministry of Machine-Building Industry proposed an urgent effort to solve problems in hydrogen bomb theory and technology and in thermonuclear materials production, and called for an attempt to conduct a test of a hydrogen bomb device in 1968.

1965

28 February: The State Council appointed Li Jue [2621 6030] as vice minister of the Second Ministry of Machine-Building Industry.

24 March: The special central commission convened its 11th meeting and called on the Second Ministry of Machine-Building Industry to complete a land-based model reactor for a nuclear submarine.

April: The swimming pool-type research and experiment reactor at the Institute of Atomic Energy was completed and increased to full power.

4 and 5 May: The special central commission convened its 12th meeting and approved in principle the site selection and construction program for the first group of projects in the third line drafted by the Second Ministry of Machine-Building Industry on 26 April. In regard to questions concerning the second nuclear experiment, Zhou Enlai instructed that the nuclear test should be "successful on the first try and completely effective."

14 May: China conducted its second nuclear test in the atmosphere above western China.

20 August: The Second Ministry of Machine-Building Industry transmitted its report "On Work Arrangements for Breakthroughs in Hydrogen Bomb Technologies" to the CPC Central Committee.

25 August: The CPC Central Committee and State Council approved and passed on the "Decisions on Uranium Ore Survey Exploration and Comprehensive Utilization (Draft)" to the State Planning Commission, Economic Commission, and National Defense Industry Office.

2 November: Deng Xiaoping, Li Fuchun, Bo Yibo, and other central leaders as well as leaders of the relevant ministry committees and provinces heard Second Ministry of Machine-Building Industry Minister Liu Qisheng's report on work by the Second Ministry of Machine-Building Industry to select plant sites for the third line. Deng Xiaoping gave some instructions.

6 November: Deng Xiaoping, Bo Yibo, and other central leaders inspected the site selected for one plant.

12 November: The Second Ministry of Machine-Building Industry established a Third Line Headquarters with Li Qisheng as general director.

30 November: The large cloud chamber at the Institute of Atomic Energy used for research on cosmic ray high energy physics was basically completed.

December: The 14th meeting of the special central commission approved in principle the Second Ministry of Machine-Building Industry's "Two-Year (1966-1967) Plan for Nuclear Weapons Scientific Research and Production."

1966

31 January to 8 March: The Second Ministry of Machine-Building Industry held a work conference and political work conference in Beijing. Central leaders, including Liu Shaoqi and Zhou Enlai, met with the delegates.

13 to 30 March: Deng Xiaoping, Bo Yibo, and other party and state leaders visited the Lanzhou Uranium Enrichment Plant, Jiuquan Integrated Atomic Energy Enterprise, and Northwest Nuclear Weapons Development Base Area.

9 May: China conducted its first nuclear experiment with thermonuclear materials (the third nuclear test) in the atmosphere above western China.

11 September: The Second Ministry of Machine-Building Industry and Shanghai Municipality issued a joint report to Premier Zhou Enlai proposing that Shanghai build a 10,000 kW pressurized-water power reactor in eastern China to generate power to improve the nuclear submarine power reactor.

20 October: The Jiuquan Integrated Atomic Energy Enterprise reactor achieved a nuclear chain reaction.

27 October: China carried out a guided missile nuclear weapons test (the fourth nuclear test).

30 October: The Central Military Commission issued a congratulatory telegram commemorating the completion of China's first production reactor.

28 December: China carried out its fifth nuclear test in western China.

1967

8 March: The Second Ministry of Machine-Building Industry and the Seventh Academy of the PLA Navy decided to establish a nuclear submarine power reactor project headquarters.

March to November: Mao Zedong, Zhou Enlai, Ye Jianying, Nie Rongzhen, and other central leaders sent telegrams instructing enterprises under the Second Ministry of Machine-Building Industry to implement military administration during the "Great Cultural Revolution" and calling on them not to permit the establishment of political ties, seizure of power, or shutdowns, and to carry out head-on education.

15 May to July 1973: Military administration was implemented in organs of the Second Ministry of Machine-Building Industry.

17 June: China's first hydrogen bomb blast test (6th nuclear test) was successful.

30 August: The Central Military Commission issued a special official letter calling for accelerated nuclear submarine development.

17 December: The State Council and Central Military Commission decided to place nuclear weapons development units in the Second Ministry of Machine-Building Industry under the National Defense Science Commission beginning 1 January 1968 (they were returned to the Second Ministry of Machine-Building Industry on 26 July 1973).

24 December: China conducted its 7th nuclear test.

1968

18 July: Mao Zedong instructed that units of the PLA be assigned to support construction of the land-based model nuclear submarine reactor.

27 December: China conducted its 8th nuclear test. This was a new thermo-nuclear test.

1969

23 September: China conducted its first underground nuclear test (9th nuclear test).

29 September: China conducted a hydrogen bomb blast test (10th nuclear test).

1970

3 January: The First Ministry of Machine-Building Industry and Second Ministry of Machine-Building Industry jointly issued the "Notice on Large-Scale Diffuser Development."

28 April: Civil engineering and installation of the land-based model nuclear submarine reactor were completed ahead of schedule.

1 July: The Second Ministry of Machine-Building Industry established a CPC core group and revolutionary committee.

15 and 16 July: Zhou Enlai listened to reports on the situation in work prior to an increase in power at the land-based model nuclear submarine reactor and instructed: "it must be safe and reliable with absolutely no mistakes and done according to standards."

17 July: Power was increased at the land-based model nuclear submarine reactor, and it reached full power on 30 July.

14 October: China conducted its 11th nuclear test.

6 November: With approval from Zhou Enlai and the Central Military Commission Administrative Group, the 15th Institute of the Navy Seventh Academy was placed under the Second Ministry of Machine-Building Industry.

November: At the Great Hall of the People, Zhou Enlai stated in regard to the type of management system that should be implemented for industrial units in the Second Ministry of Machine-Building Industry that the Second Ministry of Machine-Building Industry was not just a "ministry of explosions," but that it also should be involved in nuclear power.

15 December: While chairing a meeting of the special central commission to listen to reports on programs for nuclear power station construction, Zhou Enlai pointed out that the construction of nuclear power stations should adopt principle of "safety, suitability, economy, reliance on our own efforts."

1971

10 April: The State Council and Central Military Commission announced their "Decisions on the Question of Strengthening Leadership in Units Outside of Beijing in Research Academies Under the Direct Jurisdiction of the Second and Seventh Ministries of Machine-Building Industry and the National Defense Science Commission," which stipulated that the units would be under the dual leadership of administrative departments and provinces, municipalities, and autonomous regions.

September: China's first nuclear submarine slipped into the water.

10 September: The State Council and Central Military Commission decided to reorganize some of the uranium geological and mining employees in the Second Ministry of Machine-Building Industry into the PLA Capital Construction Engineering Corps.

18 November: China conducted its 12th nuclear test.

1972

7 January: China conducted its 13th nuclear test.

18 March: China conducted its 14th nuclear test.

25 October: The Shghnagai Municipality Nuclear Power Station Engineering Leadership Group proposed a program to build a 300,000 kW pressurized-water reactor power plant and submitted a report to the National Defense Science Commission, State Planning Commission, and State Council.

1973

8 January to 31 March: The Zhongguancun Branch of the Institute of Atomic Energy in the Second Ministry of Machine-Building Industry was transferred to the CAS to establish the High Energy Physics Institute. The Lanzhou Modern Physics Institute also was transferred to the CAS. The Shanghai Institute of Atomic Energy was transferred to Shanghai Municipality. The Reactor Engineering Institute at Fangshan in Beijing Municipality moved to Sichuan to establish the Southwest Reactor Engineering Research and Design Academy.

27 June: China conducted a hydrogen bomb test (15th nuclear test) in the atmosphere above northwestern China.

1974

31 March: Zhou Enlai chaired a meeting of the special central commission which formally approved the program for construction of a 300,000 kW pressurized-water reactor power plant in Shanghai. In addition, it called on the Second Ministry of Machine-Building Industry to focus on work to develop and finalize designs for large-scale diffusers.

13 April: The State Planning Commission issued its "Notice Concerning the Inclusion of the Shanghai Nuclear Power Plant in Plans" to the Second Ministry of Machine-Building Industry and Shanghai Municipality and included the 728 Project among state capital construction projects for 1974.

17 June: China conducted its 16th nuclear test.

1975

17 January: The Fourth National People's Congress appointed Liu Xiyao as minister of the Second Ministry of Machine-Building Industry.

27 October: China conducted its 17th nuclear test (an underground test).

1976

23 January: China conducted its 18th nuclear test.

26 September: China conducted its 19th nuclear test.

17 October: China conducted its 20th nuclear test (an underground test).

17 November: China conducted a new hydrogen bomb test (21st nuclear test).

1977

15 January: Liu Wei was appointed director of the CPC Core Group in the Second Ministry of Machine-Building Industry and minister of the Second Ministry of Machine-Building Industry.

11 August: The Second Ministry of Machine-Building Industry and Hunan Province sent their joint "Request for Instructions in Construction of a 125,000 kW Nuclear Power Plant in Hunan" to the State Council, and the plan called for its completion in 1985.

16 August: Niu Shushen and Li Jue were appointed deputy directors of the CPC Core Group in the Second Ministry of Machine-Building Industry, and Lei Rongtian, Wang Jiefu [3769 0094 4395], Su Hua [5685 5478], and Jiang Shengjie [1203 5110 7132] were appointed vice ministers of the Second Ministry of Machine Building Industry.

17 September: China conducted its 22nd nuclear test.

1978

February: Li Xiannian approved the State Planning Commission, State Construction Commission, and State Science Commission "Report on the Question of Constructing the 728 Nuclear Power Plant."

15 March: China conducted its 23d nuclear test.

12 May: The Second Ministry of Machine-Building Industry convened a work conference to formulate 3-year and 8-year plans for development of the nuclear industry and suggest ideas for the end of this century.

16 June: Zhou Tie [0719 6993] and Wang Ganchang were appointed vice ministers of the Second Ministry of Machine-Building Industry. Liu Qisheng and Zhang Xianjin were appointed advisors to the Second Ministry of Machine-Building Industry.

14 October: China conducted its 24th nuclear test.

14 December: China conducted its 25th nuclear test.

1979

31 January: Gu Mu convened a conference of leaders from the State Planning Commission, State Science Commission, State Construction Commission, First Ministry of Machine-Building Industry, Second Ministry of Machine-Building Industry, Ministry of Water Resources and Electric Power, and other ministries and commissions to study issues in construction of a 300,000 kW pressurized-water nuclear power plant in Shanghai. The conference felt that the main purpose of this project was to gain an understanding of nuclear power plant design and equipment development technologies, not to build several nuclear power plants. The work had already gotten under way so it was not appropriate to take rash actions.

16 April: Liu Qisheng, Zhang Pixu [1728 0012 4872], Zhao Jingpu [6392 2417 3877], Liu Yuzhu [0491 3768 2691], Diao Junshou [0431 4596 1108], and Wang Houshan [3769 0186 1472] were appointed vice ministers of the Second Ministry of Machine-Building Industry.



2 July: The Second Ministry of Machine-Building Industry submitted its "Request for Early Approval of Construction of Two Experimental Nuclear Power Plants" to the National Defense Science Commission.

13 September: China conducted its 26th nuclear test.

21 September: The Second Ministry of Machine-Building Industry established the Nuclear Power Bureau.

22 October: The National Defense Science Commission sent its "Request for Instructions on the Question of Nuclear Power Plant Development" to Ye Jianying and the special central commission.

1 November: The CPC Central Committee approved the establishment of a Discipline Inspection Group in the Second Ministry of Machine-Building Industry with Zhang Pixu as group director and Zhang Xianjin and Gao Xinhua [7559 2450 5478] as deputy group directors.

1980

2 January: The CPC Central Committee approved the "Summary of the Meeting of the Central Scientific Research Coordination Commission." The summary proposed that research on nuclear power plants be reinforced...that the Second Ministry of Machine-Building Industry was a ministry of the atomic energy industry, that questions regarding the peaceful uses of atomic energy should be the unified responsibility of the Second Ministry of Machine-Building Industry, and that it should organize cooperation.

22 to 28 February: The First Congress of the China Nuclear Science Society and a conference to discuss ways to have nuclear S&T make greater contributions to the four modernizations drive were held in Beijing.

25 February: The State Council approved the establishment of the China Atomic Energy Industry Company.

30 April: The "Agreement of Cooperation in the Peaceful Uses of Atomic Energy" between China and Yugoslavia was signed in Beijing.

May: China's Second Ministry of Machine-Building Industry and the Italian National Nuclear Energy Commission "Protocol on Cooperation in the Peaceful Utilization of Atomic Energy Science and Technology" was signed in Italy.

27 June: The research pressurized-heavy water reactor at the Institute of Atomic Energy went into trial operation following a major overhaul and reached criticality.

16 October: China conducted its 27th nuclear test.

1981

12 to 13 February: The Second Ministry of Machine-Building Industry and National Defense Science Commission held a joint conference which suggested that the principle for future development of the nuclear industry should be given preference to assuring military needs while shifting the focus toward the national economy.

25 March: Premier Zhao Ziyang commented on the "Request for Instructions on Principles for Readjustments in the Development of the Atomic Energy Industry," stating that he agreed with the principle of a gradual shift in the atomic energy industry toward service to national economic construction.

27 October: The Second Ministry of Machine-Building Industry decided to establish the China Taishen Enterprise Company (abbreviated as the Huatai Company) in the Shenzhen Special Economic Zone in Guangdong.

October: The "Protocol Between the PRC Science and Technology Commission and the United States Nuclear Safety Management Commission on Cooperation in Nuclear Safety Matters" was signed in Beijing.

15 to 17 December: A state examination and acceptance conference for the High-Flux Reactor Project was held at the Southwest Reactor Research and Design Academy.

1982

4 to 10 February: The State Planning Commission, National Defense Science Commission, Second Ministry of Machine-Building Industry, and China Science Society held a Joint National Isotope Work Conference in Beijing.

9 April: Zhang Chen [1728 1820] was appointed minister and CPC group secretary of the Ministry of Nuclear Industry. Liu Shulin [0491 2579 2651] became vice minister and CPC group deputy secretary. Jiang Xinxiong [5592 1800 7160] and Zhao Hong [6392 1347] became vice ministers. Jiang Shengjie became director of the Science and Technology Commission, while Wang Ganchang and Deng Jiaxian [6772 4471 0341] became deputy directors. Li Jue, Zhou Tie, Diao Junshou, and Zhang Daorong [1728 6670 1369] became ministry advisors.

16 April: The "Agreement on Cooperation in the Peaceful Utilization of Nuclear Energy" between China and Romania was signed in Beijing.

4 May: The 23d Session of the Standing Committee of the Fifth People's Congress decided to rename the Second Ministry of Machine-Building Industry the Ministry of Nuclear Industry.

22 July: Premier Zhao Ziyang visited the Northwest Nuclear Weapons Development Base Area.

28 July: Hu Yaobang met with Minister Zhang Chen and Vice Minister Jiang Xinxiong and issued discussions on questions in nuclear power construction in China.

5 October: China conducted an underground nuclear test, its 28th nuclear test.

2 November: The State Economic Commission approved the choice of Taishan in Haiyan County, Zhejiang Province as the site for the Ministry of Nuclear Industry's 300,000 kW nuclear power plant.

9 to 25 December: The Second Ministry of Machine-Building Industry held a work conference in Beijing to discuss guiding principles, goals of struggle, work steps, measures, and other questions for creating a new situation in the nuclear industry.

22 December: After an exchange of documents between China and France, the "Protocol on Cooperation Between the Chinese Ministry of Nuclear Industry and the French Atomic Energy Commission Concerning the Peaceful Utilization of Nuclear Energy" was formally signed.

25 December: The China Isotope Company was established.

1983

9 March: Zhao Ziyang chaired a meeting to discuss the question of accelerating the development of nuclear power.

March: The high-current pulsed electron beam accelerator was completed and received approval from the Ministry of Nuclear Industry.

11 March: The Ministry of Nuclear Industry Instrument and Equipment Company was founded and later changed its name to the China Nuclear Instruments and Equipment Corporation. It managed the various special instruments and equipment manufacturing plants under the Ministry of Nuclear Industry.

March: The Ministry of Nuclear Industry convened the First Civilian Work Conference. It summarized and exchanged experiences, proposed plans for the development of civilian products, formulated provisional regulations and awards methods for the development of civilian product production, and so on.

23 April: The Ministry of Nuclear Industry Science and Technology Commission was formally established, and the first expanded meeting of the S&T Commission was held in Beijing.

25 April: The Ministry of Nuclear Industry established the "China Zhongyuan Foreign Engineering Company."

4 May: China conducted its 29th nuclear test (an underground test).

May: The Ministry of Nuclear Industry convened the First S&T Achievement Work Conference and collected more than 780 achievements for extension. From them, 65 achievements with obvious socioeconomic benefits were chosen as the first group of focal extension items, and they formulated the "Trial Methods for Technical Patents in the Nuclear Industry."

1 June: Ground was broken for construction of the Qinshan Nuclear Power Plant.

20 June: The First Session of the Standing Committee of the Sixth National People's Congress appointed Jiang Xinxiong as minister of the Ministry of Nuclear Industry.

26 June: The CPC Central Committee issued a notice that Jiang Xinxiong had been appointed CPC group secretary and that Zhang Chen had been appointed advisor for the Ministry of Nuclear Industry.

24 July: Hu Yaobang visited the Northwest Nuclear Weapons Development Base Area.

3 September: The State Council established the Nuclear Power Leadership Group with Li Peng [2621 7720] as group leader and Huang Yicheng [7806 3015 6134] as deputy group leader.

5 October: Zhou Ping [0719 1627] was appointed vice minister of the Ministry of Nuclear Industry.

6 October: China conducted its 30th nuclear test (an underground test).

11 October: The 27th Conference of the International Atomic Energy Organization unanimously passed a decision to accept the PRC as a member nation.

20 October: The Ministry of Nuclear Industry established the Nuclear Industry Development Research Center.

31 October: Zhao Ziyang instructed the Ministry of Nuclear Industry to give attention to research on the question of nuclear heat supply.

9 October to 13 November: The first "National Atomic and Nuclear Science and Technology Applications Exhibition" was held at the Beijing Military Museum. Wang Zhen cut the ribbon to open the exhibition. Li Peng and Fang Yi attended the opening ceremonies. Zhao Ziyang, Hu Qili [5170 0796 4539], Tian Jiyun [3944 4764 0061], Zhang Jingfu [1728 0513 1133] and other leaders in the CPC Central Committee and State Council visited the exhibition.

17 November: The Uranium Ore Dressing Institute studied and designed the new technology "ordinary temperature extraction--ordinary temperature counter-extraction to prepare high purity tungsten trioxide" for the Guangzhou Hongxin Chemical Industry Plant. Zhao Ziyang issued instructions in issue

No 21 of HE GONGYE JIANBAO [Nuclear Industry Bulletin]: This is another major achievement in the transfer of military technologies to civilian uses. It should be encouraged and supported so that it is utilized in production and provides obvious economic benefits.

12 December: The State Council agreed with the report of the Nuclear Power Leadership Group concerning a joint venture between Guangdong and Hong Kong to construct and import a large-scale nuclear power plant in the Shenzhen Special Economic Zone.

13 December: Chen Zhaobo [7115 5128 0590] was appointed vice minister of the Ministry of Nuclear Industry.

1984

1 January: China formally joined the International Atomic Energy Organization.

4 January: The State Council agreed to the establishment of a Foreign Affairs Bureau in the Ministry of Nuclear Industry.

10 January: The Ministry of Nuclear Industry's Qinshan Nuclear Power Plant and other projects were included among key state construction projects.

27 February: The Ministry of Nuclear Industry convened a work conference. Li Peng spoke at the conference and stressed that creation of a new situation to assure the transfer of military technologies to civilian uses would be the guiding principle in development of the nuclear industry for some time to come.

10 March: The first miniature nuclear reactor developed by the Institute of Atomic Energy reached criticality during physical startup. It received ministry-level approval on 1 September.

12 March: In its "Report on Principles for Development of the Nuclear Fuels Industry in China" submitted to the State Council, the State Council Nuclear Power Leadership Group suggested principles which included basing the nuclear fuels needed to develop nuclear power in China on Chinese sources.

11 to 17 April: The Second Congress of the China Nuclear Science Society held a meeting in Beijing to discuss "How To Confront the New Technical Revolution in Nuclear Science and Technology."

15 May: Zhao Ziyang announced in his Report on Political Work to the Second Meeting of the Sixth National People Congress that "China maintains a critical attitude toward the discriminatory "Treaty on Non-Proliferation of Nuclear Weapons" and will not participate in this treaty. We do not, however, advocate the spread of nuclear weapons nor are we engaged in the spread of nuclear weapons. Neither will we help other nations develop nuclear weapons."

19 May: The Geology Bureau in the Ministry of Nuclear Industry and the Japan Power Reactor and Nuclear Fuel Industry Development Group signed a "Protocol on Regional Surveys for Uranium Ore Resources" for bilateral cooperation in a uranium ore survey in the Tengchong region of Yunnan Province.

May: China and the United States signed the bilateral "Protocol on Cooperation in the Peaceful Utilization of Nuclear Energy Between the PRC and the United States" in Beijing.

May: Li Peng was invited to visit the Federal Republic of Germany for a bilateral signing of the "Protocol on Cooperation in the Peaceful Utilization of Nuclear Energy Between the PRC and the Federal Republic of Germany."

11 August: China and Brazil signed the "Protocol on Cooperation in the Peaceful Utilization of Nuclear Energy" in Beijing.

19 September: Jiang Xinxiong and Zhou Ping [0719 1627] led a delegation to Vienna to participate in the 28th Congress of the International Atomic Energy Organization.

21 September: The first Chinese circulator at the Controlled Thermonuclear Fusion Experiment Facility at the Southwest Physics Institute was started up smoothly.

3 October: China conducted its 31st nuclear test (an underground test).

30 October: The State Council approved the establishment of the State Nuclear Safety Bureau and appointed Jiang Shengjie bureau director.

5 November: The "China Ruibao Development Company" was established, and it founded an Australian-Chinese joint venture with joint investments by Australia's (Taikenuomi) Company to manage the development of uranium ore resources and other activities.

9 December: China conducted its 32d nuclear test (an underground test).

28 December to 8 January 1985: The Ministry of Nuclear Industry held a work conference in Beijing which further clarified that the "civilization" of the nuclear industry should adhere to the principle of "focusing on the nuclear industry, economic diversification."

END